South Florida Water Management District

April 2000

Caloosahatchee Water Management Plan

Support Document

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LIST OF ABBREVIATIONS AND ACRONYMS

AC-FT	acre-feet
ADAPS	Automated Data Processing System (USGS)
AFSIRS	Agricultural Field Scale Irrigation Requirements Simulation
AGWQMN	Ambient Ground Water Quality Monitoring Network
ANOVA	Simple One-Factor Analysis of Variance
ASR	Aquifer Storage and Recovery
ATRP	Abandoned Tank Restoration Program
AWWA	American Water Works Association
BCBB	Big Cypress Basin Board
BCBWMP	Big Cypress Basin Water Management Plan
BMPs	Best Management Practices
BOD	Biochemical Oxygen Demand
BOR	Basis of Review
CAC	Caloosahatchee Advisory Committee
CARL	Conservation and Recreation Lands
C&SF Project	Central and Southern Florida Flood Control Project
CCMP	Comprehensive Conservation and Management Plan
CERP	Comprehensive Everglades Restoration Plan
CFS	cubic feet per second
CHNEP	Charlotte Harbor National Estuary Program
COD	Chemical Oxygen Demand
CR	County Road
CRCA	Caloosahatchee River Citizens Association
CREW	Corkscrew Regional Ecosystem Watershed
CUP	Consumptive Use Permit
CWMP	Caloosahatchee Water Management Plan
DBP	Disinfection By-Product
D/DBPR	Disinfectant/Disinfection By-Product Rule
DEP	Florida Department of Environmental Protection

DHI	Danish Hydraulic Institute
District	South Florida Water Management District
DO	Dissolved Oxygen
DRI	Developments of Regional Impact
DWCD	Disston Water Control District
DWMP	District Water Management Plan
DWSA	District Water Supply Assessment
DWSRF	Drinking Water State Revolving Funds
DSS	Domestic Self-Supplied
EAA	Everglades Agriculture Area
EAR	Evaluation Appraisal Report
ECP	Everglades Construction Project
ECWCD	East County Water Control District
EEL	Environmentally Endangered Lands
EPA	Everglades Protection Area
ERP	Environmental Resource Permitting
F.A.C.	Florida Administrative Code
FAS	Floridan Aquifer System
FCD	Central and Southern Florida Flood Control District
FCES	Florida Center for Environmental Studies
FDACS	Florida Department of Agriculture and Consumer Services
FDEP	Florida Department of Environmental Protection
FDOH	Florida Department of Health
FDOT	Florida Department of Transportation
FEMA	Federal Emergency Management Agency
FFA	Florida Forever Act
FFG	Functional Feeding Groups
FFWCC	Florida Fish and Wildlife Conservation Commission (*now known as FWC*)
FGCU	Florida Gulf Coast University
FGFWFC	Florida Game and Freshwater Fish Commission
FGS	Florida Geological Survey

FDHRS	Florida Department of Health and Rehabilitative Services
FS	Florida Department of Forestry
F.S.	Florida Statutes
FWC	Florida Wildlife Commission
FY	Fiscal Year
GAC	Granular Activated Carbon
GAP	Closing the Gaps in Wildlife Habitat Conservation System
GIS	Geographic Information System
GOF	Goodness of Fit
GPD	gallons per day
GPM	gallons per minute
GWUDI	Ground Water under the Direct Influence of Surface Water
HDPE	High-Density Polyethylene
IAS	Intermediate Aquifer System
IESWRT	Interim Enhanced Surface Water Treatment Rule
IFAS	Institute of Food and Agricultural Sciences
ISGM	Integrated Surface Water Ground Water Model
KOE	Kissimmee-Okeechobee-Everglades
LAI	Leaf Area Index
LEC	Lower East Coast
LFA	Lower Floridan Aquifer
LOSA	Lake Okeechobee Service Area
LWC	Lower West Coast
MAT	Model Advisory Team
MIL	Mobile Irrigation Laboratory
MFLs	Minimum Flows and Levels
mg/L	milligrams per liter
MGD	million gallons per day
MGY	million gallons per year
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding

NEP	National Estuary Program
NFIP	National Flood Insurance Program
NGVD	National Geodetic Vertical Datum
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
NPL	National Priorities List
NPS	National Park Service
NRCS	Natural Resources Conservation Service
O&M	Operations and Maintenance
P2000	Preservation 2000
PAW	Plant Available Water
PIR	Project Implementation Report
PLRG	Pollution Loading Reduction Goals
PPT	parts per trillion
PSP	Project Study Plan
PWS	Public Water Supply
RAA	Restricted Allocation Area
RDF	Root Mass Distribution
RECOVER	Restoration, Coordination, and Verification
Restudy	Central and Southern Florida Flood Control Project Comprehensive Review Study
RIB	Rapid Infiltration Basin
RO	Reverse Osmosis
RTA	Reduced Threshold Areas
RTE	Rare, Threatened, or Endangered Species
SALT	Saltwater Intrusion Database (SFWMD)
SAS	Surficial Aquifer System
SAV	Submerged Aquatic Vegetation
SDWA	Safe Drinking Water Act
SFWMD	South Florida Water Management District
SFWMM	South Florida Water Management Model
SGGE	South Golden Glades Estates

SHCA	Strategic Habitat Conservation Areas
SJRWMD	St. Johns River Water Management District
SOR	Save Our Rivers
SOW	Statement of Work
STA	Storm Water Treatment Area
SWCD	Soil and Water Conservation District
SWFRPC	Southwest Florida Regional Planning Council
SWFS	Southwest Florida Study
SWFWMD	Southwest Florida Water Management District
SWIM	Surface Water Improvement Management
TAZ	Traffic Analysis Zone
TKN	Total Kjeldahl Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
UEC	Upper East Coast
UFA	Upper Floridan Aquifer
UIC	Underground Injection Control
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USDW	Underground Source of Drinking Water
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VEC	Valued Ecosystem Component
WATBAL	Water Balance Model
WCA	Water Conservation Area
WHPA	Wellhead Protection Area
WICC	Water Independence for Cape Coral
WRCA	Water Resource Caution Area
WSTB	Water Science and Technology Board
WWTP	Wastewater Treatment Plant

Chapter 1
PLANNING PROCESS

PURPOSE AND SCOPE

The South Florida Water Management District (SFWMD) has undertaken development of long-term comprehensive regional water supply plans to provide better management of South Florida's water resources. The purpose of these water supply plans is to develop strategies to meet the future water demands of urban areas and agriculture, while meeting the needs of the environment. The planning process projects future (2020) demand and develops strategies to meet future demands. The plan also identifies areas where historically used sources of water will not be adequate to meet future demands, and evaluates several water source options to meet the projected deficit.

The *Caloosahatchee Water Management Plan* (CWMP) Planning Area is a subregion of the Lower West Coast (LWC) Water Supply Planning Area, and is linked through Lake Okeechobee to the Lower East Coast (LEC) Water Supply Planning Area. The CWMP is focused on surface water resources associated with the Caloosahatchee River. The findings of the CWMP will be incorporated into both the LWC and LEC Regional water supply plans.

During the 1997 legislative session, significant amendments were made to the Florida Water Resources Act of 1972 (Chapter 373, Florida Statutes) regarding regional water supply planning. These changes required the SFWMD to prepare a *Districtwide Water Supply Assessment* (DWSA) by July 1, 1998, and to then prepare water supply plans for regions that are anticipated to have the potential of demand outstripping available supply by the year 2020. The SFWMD had already committed to preparing water supply plans for each of its planning regions, which cumulatively cover the entire District. The DWSA affirmed that commitment. The 1997 amendments also incorporated minimum requirements of water supply plans. In many respects, these amendments also dovetailed with an existing Executive Order, 96-297.

The CWMP Support Document revises information, assumptions, and potential water source options to address statutory requirements through year 2020. Support Document information was used throughout the plan development process by the Caloosahatchee Advisory Committee (CAC) members, other agencies, counties, municipalities, utilities, and various interested parties.

BASIS OF WATER SUPPLY PLANNING

Legal Authority and Requirements

In 1972 the Florida Legislature created the water management districts to manage the state's water resources for various purposes, including water supply. The 1997

Legislature adopted more specific legislation concerning the role of the water management districts in water supply planning and development. The legislative intent is to provide for human and environmental demands, thereby avoiding competition. The legal basis of the SFWMD's water supply planning program in the Caloosahatchee Basin and LWC Planning Area is described in this section. Excerpts of specific Florida statutes and administrative codes cited in this section can be found in the *LWC Water Supply Plan*.

Water supply planning activities were first required of the state's water management districts following adoption of the Florida Water Resources Act of 1972 (Chapter 373, F.S.). The authors of *A Model Water Code* (Mahoney et al., 1972), upon which much of Chapter 373 is based, theorized that proper water resource allocation could best be accomplished within a statewide, coordinated planning framework. The *State Water Use Plan* and the *State Water Policy* were the primary documents to meet this objective.

With the passage of the legislative amendments, the Legislature eliminated the *State Water Use Plan* and provided for the development of the *Florida Water Plan*. The *Florida Water Plan* is required to include the Water Resource Implementation Rule and District water management plans.

The Water Resource Implementation Rule is intended to guide the Florida Department of Environmental Protection (FDEP) and the individual water management districts in implementing statutory directives. These directives are prescribed in the Water Resources Act (Chapter 373, F.S.), the Florida Air and Water Pollution Control Act (Chapter 403, F.S.), and, the *State Comprehensive Plan* (Chapter 187, F.S.). These statutes provide the basic authorities, directives, and policies for statewide water management, pollution control, and environmental protection. The current legal framework for water supply planning is shown in **Figure 1**.

District water management plans are intended to provide comprehensive long-range guidance for the actions of the water management districts in implementing their water supply, water quality, flood protection, and natural system responsibilities under state and federal laws. In addition to other information, the water management plans are required to include a Districtwide water supply assessment. Where the assessment indicates that sources of water are not adequate to meet demands, the development of a regional water supply plan is required. The District preempted this requirement by committing to a water supply planning initiative in the early 1990s that included developing water supply plans encompassing the entire District.

Water Supply Planning Initiative

The District has undertaken a water supply planning initiative to ensure prudent management of South Florida's water resources. This initiative began with the development of a *Water Supply Policy Document* (1991), and continued with the *District Water Management Plan* (1995), *Districtwide Water Supply Assessment* (1998), and regional water supply plans (on going).

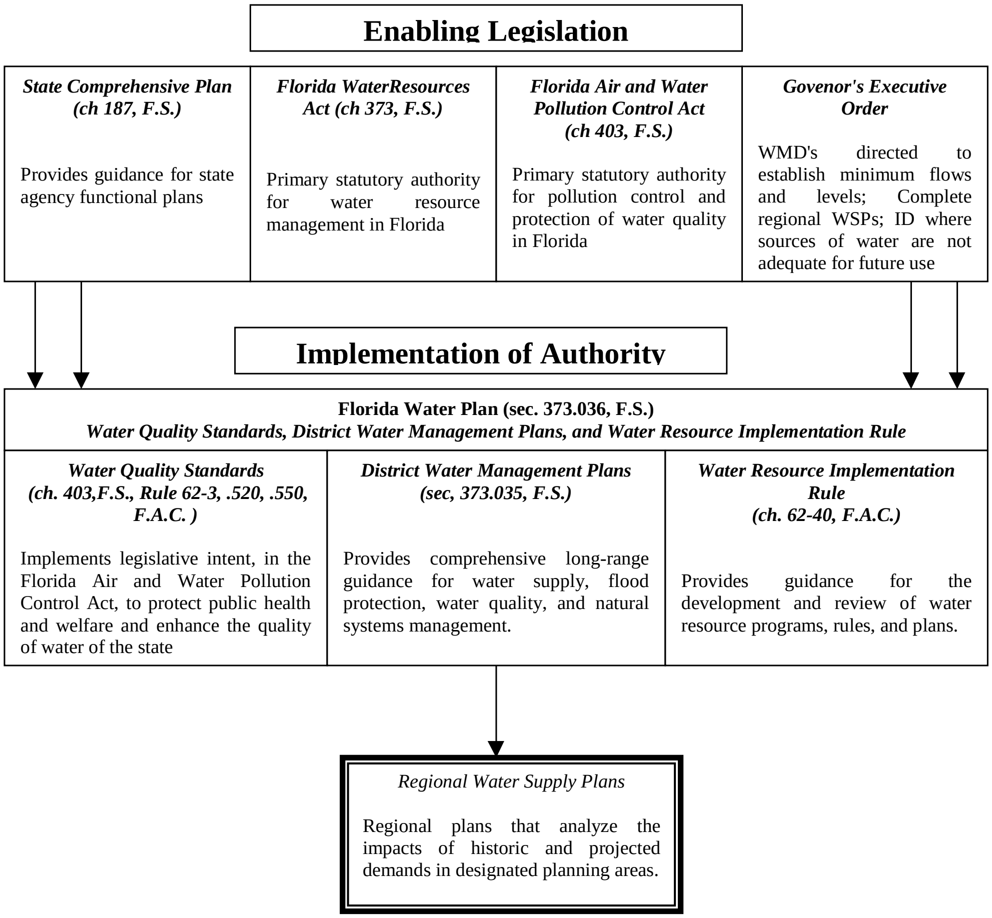


Figure 1. Legal Framework for Water Supply Planning.

Water Supply Policy Document

The District's interpretative summary of the many state statutes and rules governing the uses of surface and ground water in Florida are provided in the *Water Supply Policy Document*, approved in 1991. The six Water Use Directives, outlined in this document, guide the development of water supply plans:

1. Prevent wasteful, uneconomical, impractical, or unreasonable uses of the water resources
2. Promote economic development of the water resources consistent with other directives and uses
3. Protect and enhance environmental resources while providing appropriate levels of service for drainage, flood control, water storage, and water supply

4. Maximize levels of service for legal users, consistent with other directives
5. Preserve and enhance the quality of the state's ground and surface waters
6. Develop and maintain resource monitoring networks and applied research programs (such as forecasting models) which are required to predict the quantity and quality of water available for reasonable-beneficial uses

The CWMP vision, goals, and objectives conform to the principles established in these directives.

District Water Management Plan

The SFWMD approved the initial *District Water Management Plan* (DWMP) in April 1995, which incorporated information from the Needs and Sources Document. One outcome of new legislative revisions of Section 373.036, F.S. in 1997 was that the SFWMD would be required to develop a district water management plan that is representative of an overall strategy for future planning and implementation activities. The DWMP provides a comprehensive examination of the complex issues of water supply, flood protection, water quality, and natural systems management in South Florida based on the 20-year planning period; the DWMP incorporates established schedules for future SFWMD planning activities.

The next DWMP update includes the following:

- Scientific methodologies used in the establishment of minimum flows and levels (Section 373.042, F.S.)
- Planning region boundaries
- Revised technical data and information (Section 373.0391 and Section 373.0395)

Data and recommendations will be included from both the DWMP (approved 2000) and the *Districtwide Water Supply Assessmen*t (DWSA, July 1998). The SFWMD compiles an annual DWMP progress report on project status, performance measures, and funding requirements.

Districtwide Water Supply Assessment

Section 373.036, F.S., requires water management districts to prepare assessments of water needs and supply sources. The SFWMD, through discussions with the FDEP, bifurcated this process, and prepared a Districtwide needs and sources analysis followed by regional water supply plans. The *Water Supply Needs and Sources Document* (July 1992) made a preliminary analysis of the SFWMD's water demand and available resources. The significant role of this initial document was to provide information to local governments pursuant to Section 373.0391 and Section 373.0395, F.S., and to facilitate the completion of the DWMP. As a current data source, the July 1998 DWSA presents a composite of water demands for 1995, projections for 2020, and descriptions of surface water and ground water resources within each planning area. The water demands and projections within this CWMP Support Document were made in conjunction with the DWSA. Additional agricultural water demand and projections were used where new data was available.

The SFWMD is committed to an overall goal in water supply plans, that is derived from the *State Comprehensive Plan*:

> Florida shall assure the availability of an adequate supply of water for all competing uses deemed reasonable and beneficial and shall maintain the functions of natural systems and the overall present level of surface and ground water quality. Florida shall improve and restore the quality of waters not presently meeting water quality standards.

District water supply plans must conform to the six Water Use Directives from the *Water Supply Policy Document* (1991), referenced earlier in this chapter, if this goal is to be achieved. The state's policies endorse conservation of available supplies, diversification of potential supply sources, protection and enhancement of water quality, and protection of environmental resources. At the same time, the state and the SFWMD are required to meet the water resource needs the region's population, to provide clean water for drinking, other domestic uses, and agriculture. This goal is reflected in the planning process of the CWMP. The focus of the CWMP is on the surface water resources within the Caloosahatchee Basin. The results of the planning effort will be incoroporated into both the LWC and LEC water supply plans.

Chapter 2
THE CALOOSAHATCHEE BASIN

PLANNING AREA

The planning area for the *Caloosahatchee Water Management Plan* (CWMP) includes the entire Caloosahatchee River Basin from Lake Okeechobee to the mouth of the Caloosahatchee River Estuary. The CWMP Planning Area is shown in **Figure 2**.

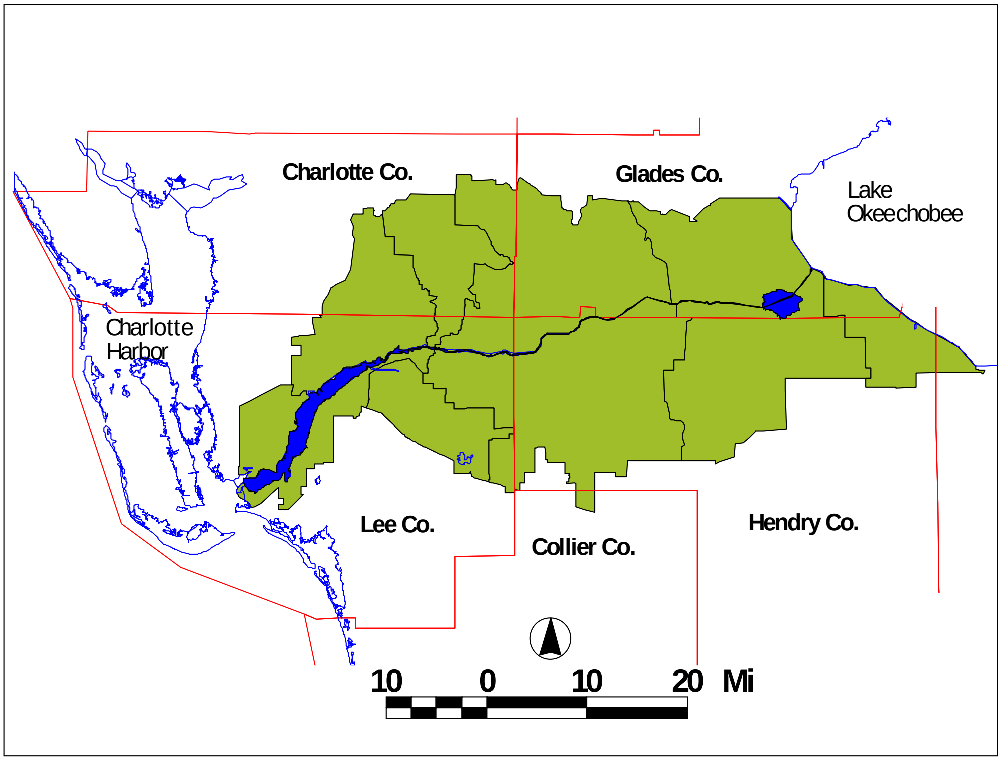


Figure 2. Caloosahatchee Water Management Plan Planning Area.

The Caloosahatchee River (C-43), along with the St. Lucie Canal (C-44), is used primarily for water releases from Lake Okeechobee when lake levels exceed water stages identified in the U.S. Army Corps of Engineers (USACE) regulation schedule. In addition to regulatory discharges for flood protection, the Caloosahatchee River receives water deliveries from the lake to maintain water levels for navigation and water supply.

THE CALOOSAHATCHEE RIVER

The Caloosahatchee River was originally a shallow, meandering river with headwaters in the proximity of Lake Hicpochee. To accommodate navigation, flood control, and land reclamation needs, the freshwater portion of the river was reconfigured into a canal known as C-43. Many canals were constructed along the banks of the river in support of the many agricultural communities within the basin. In addition, three lock-and-dam structures (S-77, S-78, and S-79) were added to control flow and stage height.

The most downstream structure (S-79) marks the beginning of the Caloosahatchee Estuary. Also refered to as the W.P. Franklin Lock and Dam, this structure maintains specified water levels upstream, regulates freshwater discharge into the estuary, and acts as an impediment to saltwater intrusion to the river. The Moore Haven Lock (S-77), located on the southwest shore of Lake Okeechobee, regulates lake waters. The Ortona Lock (S-78) aids in control of water levels on adjacent lands upstream and separates C-43 into eastern and western basins.

Today, the Caloosahatchee River extends 105 kilometers (km) from Lake Okeechobee to San Carlos Bay. The freshwater portion ranges from 50 to 130 meters (m) in width and 6 to 9 m in depth. Many of the original bends remain as oxbows along both sides of the canal. The width of the estuarine portion is irregular, from 160 m in the upper portion to 2,500 m downstream at San Carlos Bay (Scarlatos, 1988). The narrow section extends from Franklin Lock and Dam to Beautiful Island. This area has an average depth of 6 m and the area downstream of Beautiful Island has an average depth of 1.5-m (Scarlatos, 1988). The pattern and period of flow of the Caloosahatchee River is highly variable based on demand and is often negative (from west to east), possibly from irrigation usage (Drew and Schomer, 1984).

The freshwater systems of the Caloosahatchee River are divided into two distinct hydrologic units, the East and West basins. These basins include parts of Lee, Charlotte, Collier, Glades, and Hendry counties. Tributary drainage in the East Basin is more intricate than in the West Basin. Irrigation is the most important water use in this area and is controlled by an extensive network of canals that recharge the water table during the dry season and drain potential floodwaters during the wet season. Land use in the West Basin is largely agricultural. The Caloosahatchee River also serves as an important source of drinking water in the West Basin.

The Tidal Caloosahatchee Basin includes portions of Lee and Charlotte counties. The estuary length between Franklin Lock and Shell Point is 42 km and is bordered by Fort Myers on the south shore and Cape Coral on the north shore. Water discharges from the Caloosahatchee passes Shell Point and enters the Gulf of Mexico at San Carlos Bay. Because of the irregular, long, slender shape of the system, slight changes in wind, tide, runoff, or precipitation can have dramatic effects on several estuarine features such as flow, water depth, salinity, and turbidity, making characterization of the system difficult.

The hydrology of the Caloosahatchee Basin has been strongly affected by land and canal development during the past 100 years. In predevelopment times, the Caloosahatchee River was a sinuous river extending from Beautiful Island to a waterfall at the west-end of Lake Flirt. A sawgrass marsh extended from Lake Flirt to Lake Okeechobee. The predevelopment landscape had few tributaries east of LaBelle and Twelve-mile Slough connected the Okaloacoochee Slough to the Orange River (**Figure 3**).

The area east of LaBelle is very flat and there were few creeks to provide drainage. In the 1880s, the Disston Canal was dug from Lake Flirt to Lake Okeechobee to provide a navigable channel for steamboats from Lake Kissimmee through Lake Okeechobee to the Gulf of Mexico (USACE, 1957). The channel was enlarged to a 6-foot depth and 90-foot width during the period 1910 to 1930, and three locks were constructed along the canal in 1918 to improve navigation.

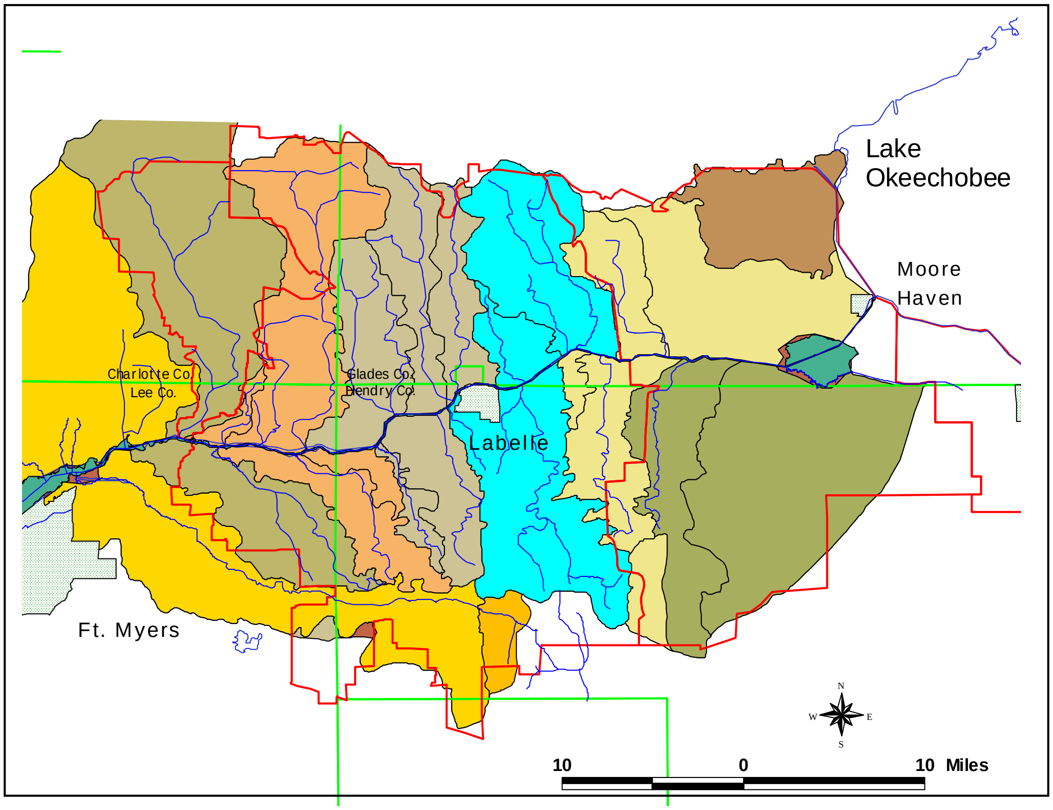


Figure 3. Predevelopment Hydrology in the Caloosahatchee Basin.

PHYSIOGRAPHY

The Caloosahatchee River Basin lies predominately within the Caloosahatchee River Valley, which rises less than fifteen feet in elevation through Lee, Hendry, and Glades counties. The valley axis follows the river from Lake Okeechobee to San Carlos Bay. The basin also includes a portion of the Immokalee Rise, an elevated flat area of predominately sandy soils to the southwest of the river; the Gulf Coastal Lowlands, which parallels and borders the western coastal areas of the state; the Caloosahatchee Incline, a valley wall that slopes upward to the north end of the river; and the DeSoto Plain, a very flat terrace extending down from the Polk Uplands of the Central Florida Highlands (Drew and Schomer, 1984).

GEOLOGY

Rock units ranging in age from Oligocene to recent are penetrated by production and monitor wells within the planning area. Formations and groups discussed in this report include the Suwannee Limestone, Hawthorn Group, Tamiami Formation, and undifferentiated terrace deposits including the Caloosahatchee Marl and Fort Thompson formation.

Oligocene Series. Rocks of Oligocene age in the planning area belong to the Suwannee Limestone. In Lee County the Suwannee Limestone is typically a yellow to pale orange, moderately indurated, very porous calcarenite interbedded with sandy phosphatic limestones and dolomites. The formation varies in thickness from 50 feet to more than 150 feet. The Suwannee Limestone is used for irrigation in Glades County.

Miocene Series. Rocks of Miocene age in the planning area belong to the Hawthorn Group. The Hawthorn Group is divided into lower carbonate and upper clastic sequences. The carbonate sequence is composed of poorly to moderately indurated phosphatic micrites and dolomites. The upper clastic sequence is composed primarily of greenish-gray phosphatic silts interbedded with coarse sand and sandstones. The base of the Hawthorn Group occurs at the contact between the Suwannee Limestone and the Lower Hawthorn/Tampa Limestone. The top of the Hawthorn Group in Lee County is identified by the first occurrence of a continuous greenish-gray dolosilt. In Hendry County the top of the Hawthorn Group occurs at a poorly consolidated sand or sandy silt beneath the biogenic limestones of the Tamiami Formation.

Pliocene Series. The Tamiami Formation in the planning area is characterized by a fosiliferous sandy limestone. In northern Hendry and southern Glades counties the formation is thin and difficult to distinguish from the younger biogenic limestones of the Fort Thompson Limestone and Calooshatchee Marl. The Tamiami Formation is thickest in southern Hendry County. It thins to the north and west, pinching out in Glades County.

Pleistocene - Recent Series. The rocks above the Tamiami Formation vary throughout the planning area, but two locally identifiable formations are of particular interest. The Caloosahatchee Marl, identified by Heilprin (1887) along the banks of the Caloosahatchee River, and the Fort Thompson Formation identified by Sellards (1919) along the banks of the Caloosahatchee River at Fort Thompson 2 miles east of LaBelle. The Caloosahatchee Marl is a discontinuous deposit of unconsolidated sand and sandy marl with abundant marine mollusk fossils.

The Fort Thompson Formation unconformably overlies the Caloosahatchee Marl. The formation is of Pleistocene Age and consists of alternating beds of marine shells and freshwater limestones.

SOILS

The soils of the Caloosahatchee River Basin are predominately Spodosols with some Entisols, Histols south of the river, and miscellaneous types in coastal areas. Spodosols are dominated by somewhat poorly to poorly drained sandy soils with dark sandy subsoil layers. They have a subsurface zone where there has been an accumulation of iron, aluminum, and/or organic matter that has cemented into a layer that may inhibit water flow. Entisols are new or recent soils of limestone origin, underlain by marl and/or limestone. They are dominated by very poorly drained, coarse and thin, sandy soils. Histols are organic soils such as muck and peat. They are very poorly drained soils underlain by marl and/or limestone. Coastal sediments mostly consist of Entisols and Histols.

CLIMATE

The Caloosahatchee Basin is located in an area that overlaps both a humid subtropical and a tropical savanna climate (Koppen Climate Types). A tropical savanna climate is characterized by more sharply delineated wet and dry seasons and monthly temperature averages greater than 64 °F. In the wet season, monthly rainfall may exceed 10 inches. A humid subtropical climate has less extreme rainfall fluctuations between wet and dry seasons and some months have an average temperature less than 64 °F.

Average yearly rainfall is approximately 52 inches within the basin, with monthly averages ranging from 2 to 10 inches. Two-thirds of the annual rainfall occurs in the wet season from May to October. There is also a high variability in rainfall at different locations in the basin (**Figure 4**). The inland portion of the basin receives more rain than the coast during the dry season (**Figure 5**). On average the wet season rainfall is greater along the coast. Although November is the driest month, April is the month with the greatest water use demand.

Thunderstorms are frequent during the wet season in Southwest Florida. In Lee County, thunderstorms occur on every two out of three days between June and September (Fernald and Purdum, 1998). Storms are usually brief but intense and peak during the late afternoon or early evening hours.

Tropical storms and hurricanes that affect the area originate in the Atlantic Tropical Cyclone Basin. This area includes the North Atlantic Ocean, the Caribbean Sea, and the Gulf of Mexico. Hurricane season extends from June through November and peaks in September and October when ocean temperatures are warmest and humidity is highest. Major effects from these storms are flooding, from rainfall and wind-generated tides and waves, storm surge, wind damage, and flushing of the river and estuary.

Water use demand is strongly related to evapotranspiration. Evapotranspiration (ET) is the sum of evaporation and transpiration and is commonly expressed in inches per year over a land area. Evapotranspiration is driven by solar radiation subject to the availability of water. Potential ET (PET), the evapotranspiration that would occur from a

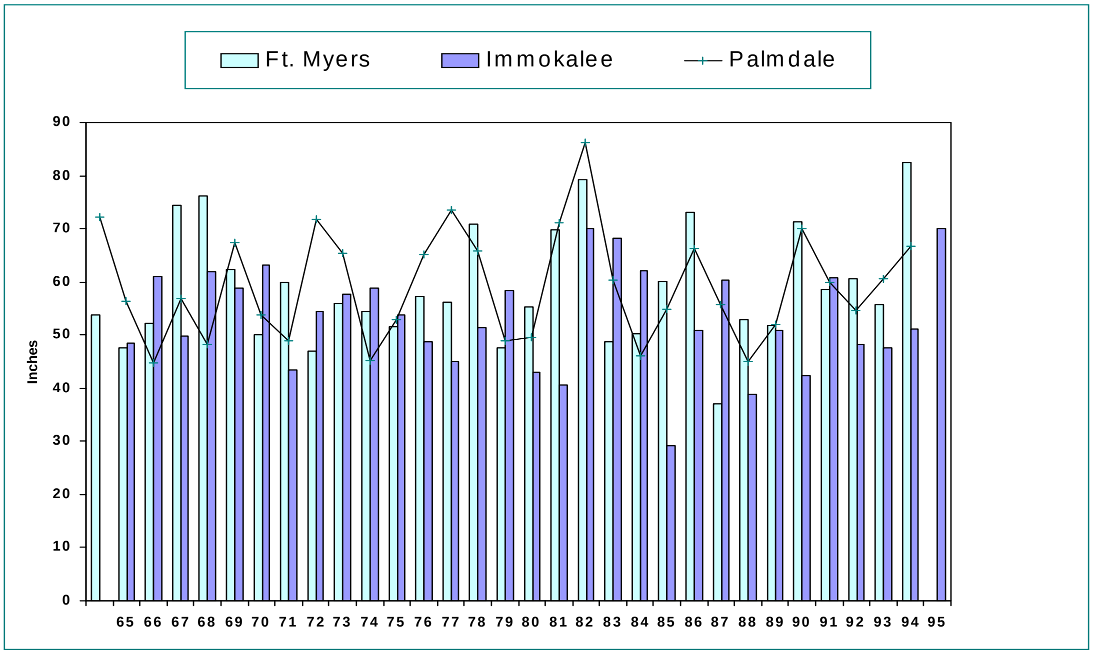


Figure 4. Variation from Annual Average Rainfall in the Caloosahatchee Basin.

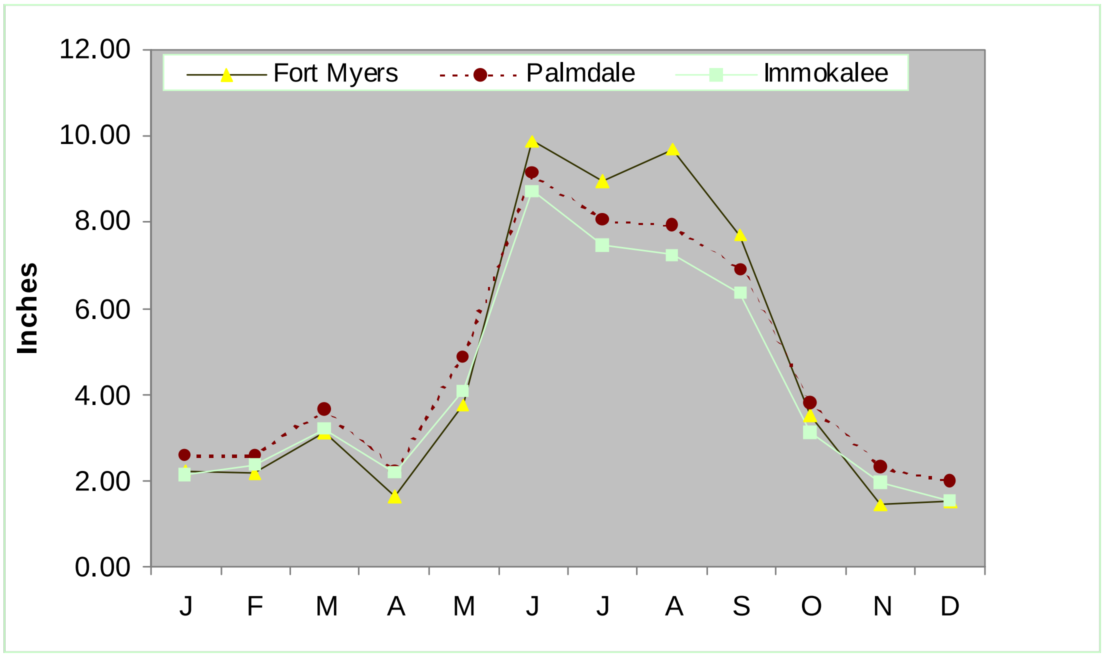


Figure 5. Spatial Variability in Average Monthly Rainfall in the Caloosahatchee Basin.

well-watered short grass is approximately 59 inches per year in Southwest Florida. The actual ET is approximately 45 inches indicating the lack of available water during the dry-season. Annual PET varies from year to year as a function of local cloud cover as well as long term cyclic effects (**Figure 6**). The excess of average precipitation over ET is equal to the combined amounts of average surface water runoff and average ground water recharge. The ET increases from Fort Myers to Lake Okeechobee as a result of decreasing cloud cover.

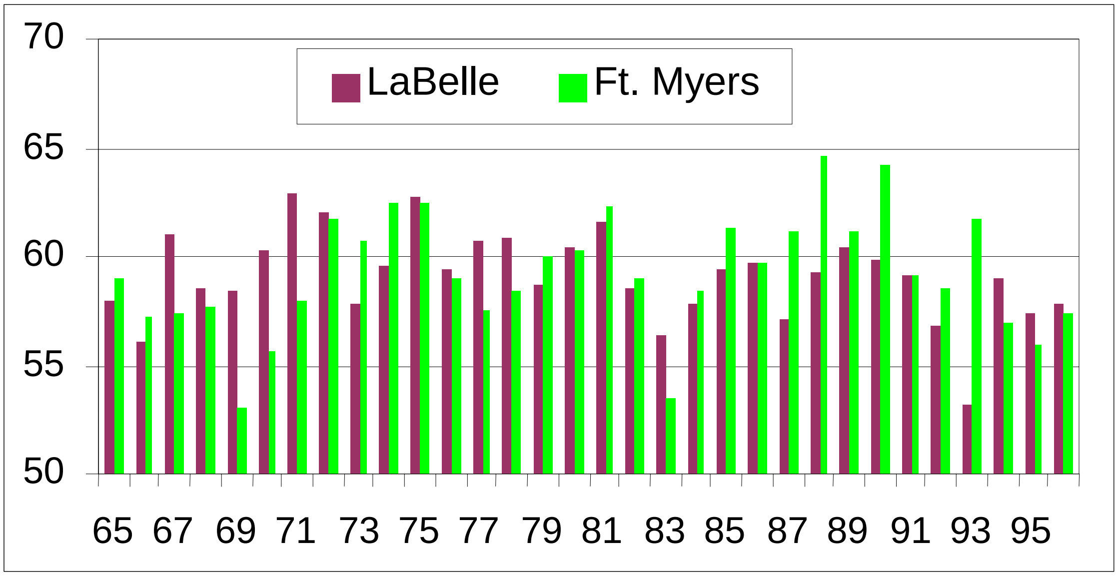


Figure 6. Annual and Spatial Variation in Potential Evapotranspiration in Southwest Florida.

WATER QUALITY

A critical relationship exists between water quality and human activity, including the withdrawal of water for supply. Increased withdrawals may cause a rise in the concentrations of impurities in the remaining water. Other human activities such as waste disposal and pollution spillage have the potential of degrading ground and surface water systems.

Water quality within the Caloosahatchee Basin is threatened by altered freshwater inputs, nutrient loads from agricultural activities, anthropogenic organic compounds, trace elements, as well as overall urban growth and development within the basin. The integrity of riverine and estuarine ecosystems is dependent on water quality. As water quality diminishes, so does the overall quality of the system.

In 1976, it was determined that water quality data was needed to determine the health of the Caloosahatchee River. A baseline water quality database was created in 1978, yielding a database, which has helped the SFWMD determine management practices within the Caloosahatchee Basin. Recently, data has been collected and complied from Lee County, the City of Cape Coral, East County Water Control, and the SFWMD to evaluate the water quality from the urban portion of the Caloosahatchee Basin. Average nutrient concentrations were calculated for individual subbasins and primary basins, and average nutrient loads were calculated for the primary basins.

The SFWMD is continuing water quality monitoring within the Caloosahatchee River through contracts with local and state agencies. Several projects incorporate water quality monitoring, including the SFWMD's VEC (Valued Ecosystem Component) study.

The Florida Center for Environmental Studies (FCES) is currently monitoring eight water quality sites within the Caloosahatchee River and Estuary System. These sites are between Shell Point, at the mouth of the river, to just above S-79 W.P. Franklin Lock. Each of the eight sites are monitored monthly and samples are taken from two fixed depths within the water column. The FCES is also performing water quality biomonitoring using the freshwater grass *Vallisneria americana* (tape grass) to determine the effects of freshwater pulsing from Lake Okeechobee. This data will help to determine a pulse schedule that will help ensure the integrity of the freshwater grass community as well as the estuarine ecosystem.

Environmental Research and Design Inc., a consulting firm from Orlando, will conduct event sampling. Their data will be used to determine nutrient loading in the Caloosahatchee Estuary and the response of estuarine nutrient concentrations to external inputs. By identifying rates of nutrient loading from wastewater treatment facilities, and rivers and streams, nutrient inputs can be ranked in order of importance. The project will provide a data set that can be used to quantify the degree to which nutrient concentrations in the estuary depend on loading from external sources.

The U.S. Geological Service was contracted to sample bottom sediments from 35 sites in the Calooshatchee Estuary, including upstream of S-79. This project provided the SFWMD with a complete assessment of total nitrogen, phosphorus, and potential toxic substances within the estuary. Other sample sites for the project were located in San Carlos Bay, Estero Bay, and Pine Island Sound.

EXISTING LAND USE

In general, land use in the Caloosahatchee Water Management Planning Area is predominantly rural and agricultural in nature in the eastern portion of the basin and urban in the western portion of the basin (**Figure 7**).

The predominant land use in the Caloosahatchee Water Management Planning Area is agricultural and is expected to remain so in the future. Citrus is the dominant irrigated crop in the basin and occupies over 91,000 acres, according to the 1995 Land Use

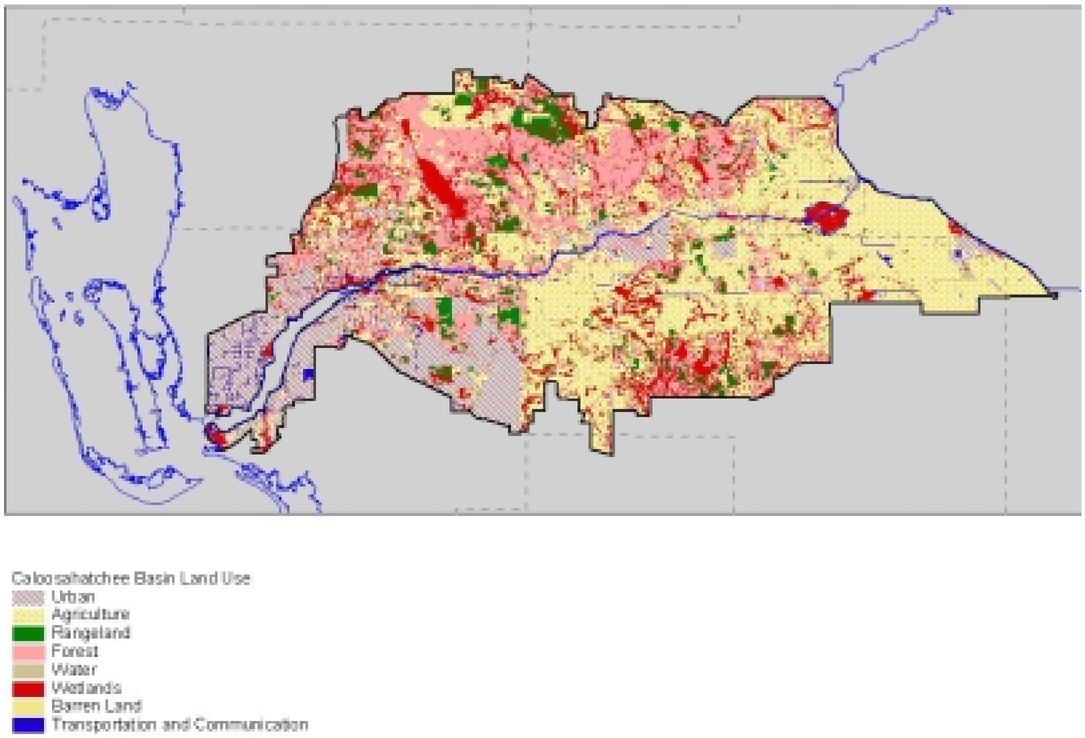


Figure 7. 1995 Caloosahatchee Basin Land Use.

Coverage (SFWMD). Over the past two decades, Southwest Florida has had the fastest growing citrus acreage in the state. This is associated with the movement of citrus southward from Central Florida following several severe winter freezes in the mid-1980s.

Sugarcane, with an estimated 75,000 acres, according to the 1995 Land Use Coverage, closely follows citrus in dominance. It is produced in the Caloosahatchee Basin in close vicinity to Lake Okeechobee, in Hendry and Glades counties, where transportation costs to the mills can be minimized. Sugarcane acreage has continued to increase since 1995, and is expected to continue to increase in the future.

Native/natural land uses are also predominant in the basin, however can be expected to decrease as the basin is further transformed into agriculture and urban uses. Urban land use follows behind, and is predominant in the western portion of the basin.

NATURAL SYSTEMS

The Caloosahatchee Basin contains a variety of natural systems, ranging from an estuarine system with mangrove forests and seagrass beds to inland freshwater-forested shrub, herbaceous wetlands, and upland habitats. Although physically separate, these systems form an ecological continuum.

Estuary

The Caloosahatchee River Estuary is a large system where the waters of the Gulf of Mexico mix with the freshwater inflows from the river, sloughs, and sheetflows in the basin. The area is characterized by a shallow bay, extensive seagrass beds, and sand flats. Extensive mangrove forests dominate undeveloped areas of the shoreline. Southwest Florida estuaries are used by more than 40 percent of Florida's rare, endangered, and threatened species.

Coastal areas subject to tidal inundation support extensive mangrove forests and salt marsh areas. Coastal mangroves discourage erosion from storms and high tides, and assimilate nutrients to produce organic matter, which forms the base of the food chain. Four species of mangroves as commonly found along the South Florida coastline: White mangrove (*Laguncularia racemosa*); Black mangrove (*Avicennia germinans*); Red Mangrove (*Rhizophora mangle*); and Buttonwood (*Conocarpus erectus*). Mangroves and salt marsh communities serve as important nursery and feeding grounds for many economically important species of finfish and shellfish, which in turn support migratory waterfowl, shore bird and wading bird populations. These brackish water communities were once commonly distributed along the entire coastline but are now found in greatest abundance in southwestern Collier County and southern Lee County.

Maintenance of appropriate freshwater inflows is essential for a healthy estuarine system. Preliminary findings indicate that optimum inflows to the Caloosahatchee Estuary should have mean monthly values between 300 and 2,800 cubic feet per second (cfs). Average daily flows between January 1988 and June 1999 were approximately 500 cfs. Low flows of 0 cfs and high flows as high as 17,283 cfs were recorded during the same period. Excessive freshwater inflows to the estuary result in imbalances beyond the tolerances of estuarine organisms. The retention of water within upland basins for water supply purposes can reduce inflows into the estuary and promote excessive salinities. Conversely, the inflow of large quantities of water into the estuary as a result of flood control activities can significantly reduce salinities and introduce storm water contaminants. In addition to the immediate impacts associated with dramatic changes in freshwater inflows, long-term cumulative changes in water quality constituents or water clarity may also adversely affect the estuarine community.

Estuarine biota is well adapted to and depends upon natural seasonal changes in salinity. The temporary storage and concurrent decrease in velocity of floodwaters within upstream wetlands aid in controlling the timing, duration, and quantity of freshwater flows into the estuary. Upstream wetlands and their associated ground water systems serve as freshwater reservoirs for the maintenance of baseflow discharges into the estuaries, providing favorable salinities for estuarine biota. During the wet season, upstream wetlands provide pulses of organic detritus, which are exported downstream to the brackish water zone. These materials are an important link in the estuarine food chain.

Tape grass, *Vallisneria americana*, is one of the dominant submerged aquatic plants in the upper Caloosahatchee River Estuary, and occurs in well-defined beds in shallow waters. *Vallisneria americana* is thought to be an important habitat for a variety of freshwater and estuarine invertebrate and vertebrate species, including some commercially and recreationally important fish (Appendix C). Additionally, it can serve as a food source for the Florida manatee.

Estuaries are important nursery grounds for many commercially important fish species. Many freshwater wetland systems in the planning area provide baseflows to the estuary. Wetlands as far inland as the Okaloacoochee Slough in Hendry County contribute to the baseflows entering the estuarine system. Maintenance of these baseflows is crucial to propagation of many fish species, such as grouper, snapper, and spotted sea trout, which are the basis of extensive commercial and recreational fishing industries.

The estuarine environment is sensitive to freshwater releases, and disruption of the volume, distribution, circulation, and temporal patterns of freshwater discharges could place severe stress on the entire ecosystem. Such salinity patterns affect productivity, population distribution, community composition, predator-prey interactions, and food web structure in the inshore marine habitat. In many ways, salinity is a master ecological variable that controls important aspects of community structure and food web organization in coastal systems (Myers and Ewel, 1990). Other aspects of water quality, such as turbidity, dissolved oxygen, nutrient loads, and toxins, also affect functions of these areas (USDA, 1989; Myers and Ewel, 1990).

Research is currently being conducted by the Florida Center for Environmental Studies, in conjunction with the SFWMD, to investigate the in situ influence of freshwater inflow and salinity on tape grass and to determine if freshwater inflow requirements are needed to permit a "healthy", thriving ecosystem in the upper portions of the Caloosahatchee Estuary. This work will help the SFWMD in its charge to make informed management decisions regarding optimal flow volumes and discharge schedules to preserve, increase, or maintain existing submerged aquatic vegetation present in the upper portions of the Caloosahatchee Estuary as well as the communities of organisms associated with it.

Also, the SFWMD and the USACE are conducting a research study to characterize seasonal fluctuations of Submerged Aquatic Vegetation (SAV) in the upper Caloosahatchee Estuary, lower Caloosahatchee Estuary, San Carlos Bay and Pine Island Sound. SAV will be mapped, on the basis of distribution and proximity to significant freshwater input, using Submersed Aquatic Vegetation Early Warning System, which was developed by scientists at the USACE-Waterways Experiment Station. This project will provide information on spatial and temporal variations in biotic communities needed to determine biotic status and trends. Furthermore, the project will provide information on the effect of management actions on ecosystems to researchers and managers assessing the success of future water management policies designed to protect and enhance SAV communities.

Additionally, the University of Florida Coastal and Oceanographic Engineering Department are developing a coupled circulation/water quality model for the Charlotte Harbor Estuarine system for the SFWMD. The model will be developed in three phases. During Phase I, a preliminary 3-D circulation model will be developed and calibrated with available hydrodynamic data and then applied to address the impact of the Caloosahatchee River Estuary on circulation in Pine Island Sound, with particular focus on the effect of the Sanibel Causeway. This is scheduled for completion December 1999. Phase II will review and analyze available water quality data and a 3-D water quality model will be developed. An assessment of the effects of the Sanibel Causeway on circulation and salinity will be accomplished. Phase III will calibrate the coupled hydrodynamics and water quality models and apply them to address the impact of loading from the Caloosahatchee Basin on the water quality in the Caloosahatchee Estuary, San Carlos Bay, and Pine Island Sound. Phase II is scheduled for completion in late 2000 and Phase III in 2001.

Inland Resources

Inland portions of the Caloosahatchee Basin include freshwater swamps, sloughs, and marshes. These wetland areas serve as important habitat for a wide variety of wildlife and have numerous hydrological functions. Before development of South Florida, inland areas were comprised of vast expanses of cypress and hardwood swamps, freshwater marshes, sloughs, and flatwoods. Scattered among these systems were oak/cabbage palm and tropical hammocks, coastal strand and xeric scrub habitats. A large portion of the area contained seasonally flooded wetlands which sheetflowed fresh water from northeast to southwest. Water bodies within the Caloosahatchee Basin include natural lakes, man-made surface water impoundments, rivers, and creeks.

Wetlands

Wetlands are transitional lands between uplands and aquatic systems and are typically defined by vegetation, soils, and hydrology. Chapter 62-340, Florida Administrative Code (F.A.C.), provides the statewide methodology for delineating wetlands in Florida. In part, Chapter 62-340 includes the following definition of wetlands:

> Those areas that are inundated or saturated by surface water or ground water at a frequency and a duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soils. Wetlands within the planning area include swamps, marshes, cypress domes and strands, sloughs, wet prairies, wetland hardwoods, and mangrove swamps.

Wetlands perform a number of hydrologic and biologic functions valuable to man. Hydrologic functions include receiving and storing surface water runoff. This is important in controlling flooding, erosion, and sedimentation. Surface water that enters a wetland is stored until the wetland's overflow capacity is reached and water is slowly released downstream. As the flow of water is slowed by wetland vegetation, sediments in the water (and chemicals bound to the sediments) drop out of the water column, potentially improving water quality. Additionally, within cypress wetlands, the trees are deciduous which reduces water loss due to transpiration during the dry season. Wetlands also function hydrologically as ground water recharge-discharge areas. Wetlands recharge the ground water when the water level of a wetland is higher than the water table.

Conversely, ground water discharge to wetlands may occur when the water level of the wetland is lower than the water table of the surrounding land.

Biological wetland functions include providing habitat for fish and wildlife, including organisms classified as endangered, threatened, or species of special concern. Some species depend on wetlands for their entire existence, while other semi-aquatic and terrestrial organisms use wetlands during some part of their life cycle. Their dependence on wetlands may be for over-wintering, residence, feeding and reproduction, nursery areas, den sites, or corridors for movement. Wetlands are also an important link in the aquatic food web. They are important sites for microorganisms, invertebrates, and forage fish, which are consumed by predators such as amphibians, reptiles, wading birds, and mammals.

Inland, or freshwater, wetlands within the planning area can be grouped into three major categories based in hydroperiod: permanently flooded or irregularly exposed; seasonally or semipermanently flooded; temporarily flooded or saturated; and upland. The Florida Land Use Cover and Classification System (FLUCCS) was used to delineate wetland systems within the Caloosahatchee Basin. The FLUCCS map was created in 1998 using 1994-1995 aerial photography and is the most accurate representation of the Basin. The hydroperiod categories were created by combining FLUCCS coverage classifications with the National Wetlands Inventory hydrologic classifications. The hydrologic categories are broadly defined as:

Permanently Flooded or Irregularly Exposed. Water covers the substrate throughout the year in all years or the substrate is exposed by tides less often than daily. This corresponds to lakes, reservoirs, embayments, tidal mangrove swamps, salt marsh, and major springs (FLUCCS codes of open water, level-1 = 500).

Seasonally or Semipermanently Flooded. Surface water persists throughout the rainy season and much of the dry season in most years. When surface water is absent, the water table is at or very near the land surface. Seasonally flooded soils are saturated. This corresponds to swamps, sloughs, mixed wetland hardwoods, cypress, wetland forest mixed, freshwater marshes sawgrass or cattail, wet prairies, emergent and submergent aquatic vegetation (FLUCCS codes of wetlands, level-1 = 600).

The hydric pine flatwoods habitat is dominated by a southern slash pine (*Pinus elliottii var. densa*) upperstory with a wetland plant understory, unique to South Florida. The wetland understory can be any, or a variety, of wetland plant community types including wet prairie, freshwater marsh, freshwater slough, freshwater seasonal ponds, cordgrass prairie, beakrush prairie, scrub cypress, dwarf cypress, or hatrack cypress. Hydric pine flatwoods are distinct from mesic and xeric pine flatwoods in the absence of understory dominance by saw palmetto (*Serenoa repens*) and xeric scrub species. Mid-story plants of hydric pine flatwoods include the nearly ubiquitous natives: cabbage palm (*Sabal palmetto*); wax myrtle (*Myrica cerifera*); strangler fig (*Ficus aurea*); the exotic invaders: Brazilian pepper (*Schinus terebinthifolius*) and melaleuca (*Melaleuca quinquinervia*); and the shrub species characteristic of mixed hardwood swamp forest and cypress forest of South Florida: red maple (*Acer rubrum*), dahoon holly (*Ilex cassine*), and buttonbush (*Cephalanthus occidentalis*). The hydric pine flatwoods act as both uplands, in dry season, and wetlands, in the summer and fall. Soils are sandy and permeable with some marl in Collier County. Hydric pine flatwoods provide habitat for 10 federal and 75 state listed species.

Temporarily Flooded or Saturated. Surface water is present for brief periods during the rainy season, but the water table usually lies well below the soil surface for most of the year. Plants that grow in both uplands and wetlands are characteristic of this water regime. The substrate is saturated to the surface throughout the rainy season or for extended periods during the rainy season in most years. Surface water is seldom present. This corresponds to cypress-pine-cabbage palm, wet prairie-with pine, intermittent ponds, pine-mesic oak, brazilian pepper, melaleuca, and wax myrtle-willow (FLUCCS codes of level-3 = 600).

Two significant natural wetland systems in the Caloosahatchee Basin are Twelve Mile Slough and the Okaloacoochee Slough. Both are located south of the river. The Twelve-Mile Slough is located in Hendry County and is a tributary to the much larger and regionally significant Okaloacoochee Slough. It covers 3,300 acres and contains a mosaic of freshwater wetlands, as well as pine flatwoods and oak/cabbage palm hammocks. Surface water storage in the numerous wetlands provides for ground water recharge of the underlying surficial aquifer and provides surface water supply to the Caloosahatchee River.

A portion of the Okaloacoochee Slough is located in the Caloosahatchee Basin, in Hendry County. It flows both north, toward the Caloosahatchee River, and south toward Collier County and is a major headwater for the Fakahatchee Strand and the Big Cypress National Preserve. This slough system is composed largely of herbaceous plants with trees and shrubs scattered along its fringes and central portions. Its extensive network of sloughs and isolated wetlands store wet-season runoff from the surrounding uplands and provide year-round baseflow to downstream natural areas. The Okaloacoochee Slough, Harn's Marsh, and Orange River system provide habitat for a variety of wildlife such as the endangered Florida panther.

The mesic oak hammock is a closed canopy forest, dominated by temperate evergreen tree species, primarily live oak, with cabbage palms and some pines, that is naturally protected from fire by its position on the landscape, often adjacent to rivers, streams, and swamps. Tropical species are common in the shrub layer and become increasingly important in the canopy at the southern end of the range. Soils are moist due to a dense litter layer and humid conditions under the closed canopy, but are rarely inundated. Mesic hammocks provide habitat for five federal and 23 state listed species.

Wetland systems north of the river include portions of Fisheating Creek and Telegraph Cypress Swamp. Fisheating Creek is a major wetland system in western Glades County. It is an extensive riverine swamp system that forms a basin covering hundreds of square miles. Although Fisheating Creek is located in the Kissimmee Basin Planning Area, it delineates the northern boundary of the Caloosahatchee Basin. Fisheating Creek is the only free flowing tributary to Lake Okeechobee. The creek attenuates discharges from heavy storm events and improves water quality before the storm water enters the lake. The creek also serves as a feeding area for wading birds such as the endangered wood stork, white ibis, and great egrets, when stages in the marshes surrounding Lake Okeechobee are too high.

Telegraph Cypress Swamp is located in eastern Charlotte County. It is a diverse system with a mixture of hydric flatwoods, cypress strands, and marshes. Within Lee County there are several free flowing creeks that enter the river west of S-79 such as Hancock, Yellow Fever, Powell, Doughtrey, Bedman and Hickey. The headwaters for Hancock, Yellow Fever, Powell, and Doughtrey creeks are in Charlotte County.

Thirty-five side channels, or oxbows, of various sizes and geomorphic configurations are found along the channelized river from the town of LaBelle down to the W.P. Franklin Lock and Dam. The ecological condition of these oxbows varies from reasonably good, in those few with significant flow-through, to very poor in those where flow is restricted or blocked and significant organically rich sediments have accumulated (Cummins and Merritt, 1999). The long-term management objective for these oxbows is to enhance their capacity as water quality filters and off-channel water storage during wet periods by rehabilitating them to flow-through conditions.

Research is being conducted to assess the present ecological state of the river's oxbows. Ten oxbows have been selected for a study that includes water quality sampling; remote sensing and GIS mapping; channel geomorphic and plant bed measurements; plant bed and sediment macroinvertebrate functional groups; and fish diversity and functional groups. To date, the macroinvertebrate functional group analysis has been completed and recommendations have been made for oxbow restoration based on this data. The other components of the study are to be completed in April 2000. At that time, final recommendations for oxbow restoration will be made.

Uplands

Uplands are an important part of the natural system. Upland communities in the Caloosahatchee Basin include pine flatwoods, tropical hammocks, mesic oak, dry prairie, and xeric scrub communities, with flatwoods being the dominant upland habitat. Flatwood communities are divided into two types: dry and hydric. Dry flatwood communities are characterized by an open canopy of slash pine with an understory of saw palmetto. However, dry flatwoods are located in a slightly higher elevation in the landscape and are rarely inundated. Hydric flatwood communities (wetlands) are vegetatively similar to dry flatwoods.

Large areas of flatwoods are found throughout Hendry and Lee counties, as well as portions of Charlotte, Glades, and Collier counties. Upland flatwoods are the native habitats most affected by the expansion of citrus into Southwest Florida. Flatwoods are important habitat for a number of threatened and endangered species such as the Florida panther, Florida black bear, eastern indigo snake, red-cockaded woodpecker, and the gopher tortoise. Pine flatwoods have a greater richness of vertebrate species than either sand pine or dry grass prairies (Myers and Ewel, 1990).

Tropical hammocks are rare in the basin. This diverse woody upland plant community occurs on elevated areas, often in Indian shell mounds along the coast, or on marl or limestone outcroppings inland. As a result of urban development, tropical hammocks are among the most endangered ecological communities in South Florida.

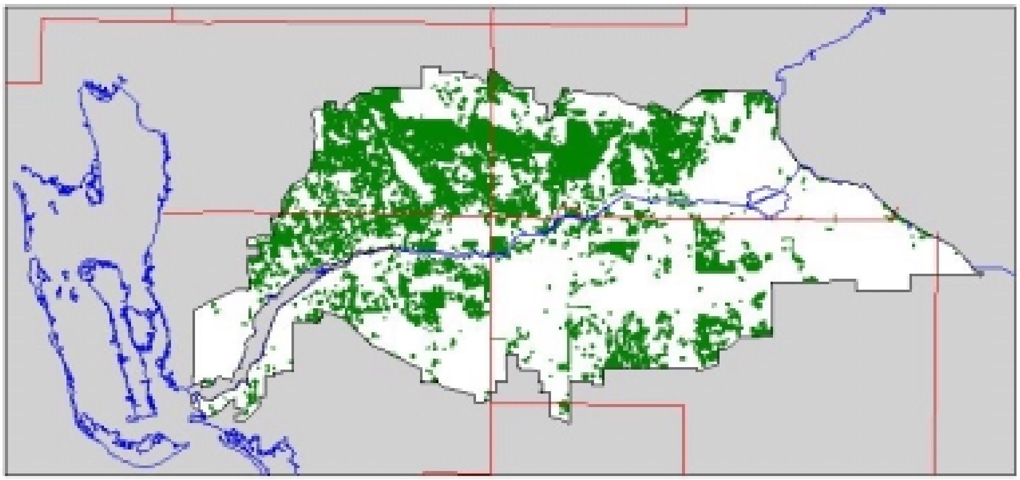
Xeric, sand pine, and oak scrub communities most commonly occur along ridges and ancient dunes. They are often associated with relic sand dunes formed when sea levels were higher. These well-drained sandy soils are important aquifer recharge for coastal communities. The sand pine and oak scrub is the most endangered ecological community present within the planning area. It is rapidly being eliminated by conversion to other land uses.

Upland plant communities serve as recharge areas, absorbing rainfall into soils where it is distributed into plant systems or stored underground within the aquifer. Ground water storage in upland areas reduces runoff during extreme rainfall events, while plant cover reduces erosion and absorbs nutrients and other pollutants that might be generated during a storm event. With few exceptions the functions and values attributed to wetlands also apply to upland systems. Upland/wetland systems are ecological continuums, existing and adapting to geomorphic variation. The classification of natural systems is artificial and tends to convey a message that they survive independently of each other. In reality, wetland and upland systems are interdependent. To preserve the structure and functions of wetlands, the linkage between uplands and wetlands must be maintained (Mazzotti et al., 1992). Caloosahatchee Basin uplands and wetlands (1995 FLUCCS coverages) are shown in **Figure 8**.

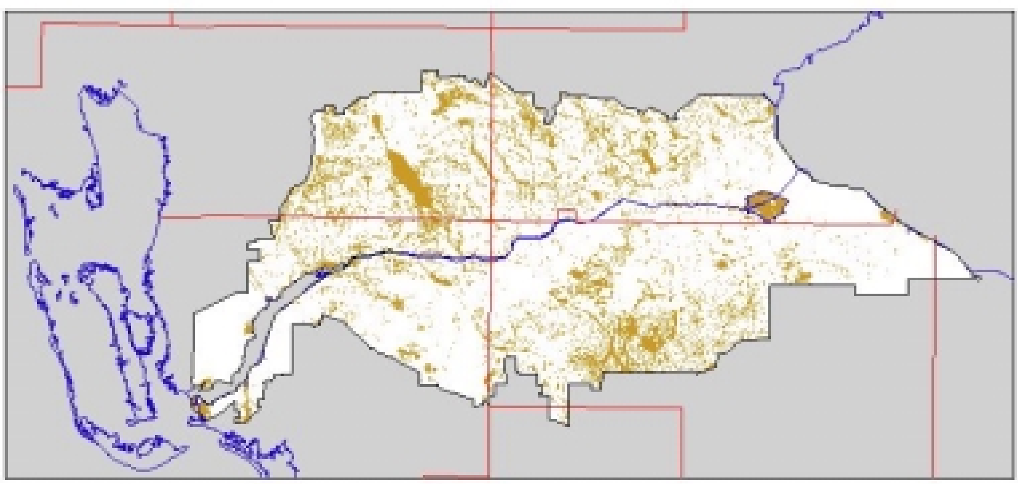
Fauna

Southwest Florida, in general, has a rich diversity of native fauna. These include endemic and subtropical species that cannot be found anywhere else in the United States. The Caloosahatchee Basin supports a diverse and abundant array of fish and wildlife species, including many endangered and threatened species (**Table 1**). The Caloosahatchee Estuary serves as a particularly important center of abundance in the state for the Florida manatee. Likewise, Telegraph Swamp and the Corkscrew Regional Ecosystem are Strategic Conservation Areas for the Florida panther (Cox et al., 1994).

The Florida Fish and Wildlife Conservation Commission in their Closing the Gaps in Wildlife Habitat Conservation System (GAPS) described habitat in Florida that should be conserved if key components of the state's biological diversity are to be maintained. Habitat areas identified for each species are called Strategic Habitat Conservation Areas (SHCA) because of their importance in providing some of Florida's rarest species with the habitat needed for long-term persistence (Cox et al., 1994).



Caloosahatchee Basin Uplands (1995 FLUCCS)



Caloosahatchee Basin Wetlands (1995 FLUCCS)

Figure 8. Caloosahatchee Basin Uplands and Wetlands.

Table 1. Threatened, Endangered, and Species of Special Concern in the Caloosahatchee Basin (USFWS, 1998 and FGFWFC, 1997).

Scientific Name	Common Name	Federal Status	State Status
Amphibians			
Rana capito	Gopher frog		SSC
Reptiles			
Alligator mississippiensis	American alligator	T(S/A)	SSC
Caretta caretta	Loggerhead sea turtle	T	T
Chelonia caretta	Green sea turtle	E	E
Dermochelys coriacea	Leatherback sea turtle	E	E
Drymarchon corais couperi	Eastern indigo snake	E	T
Eretmochelys imbricata	Hawksbill sea turtle	E	E
Gopherus polyphemus	Gopher tortoise		SSC
Lepidochelys kempii	Kemp's ridley sea turtle	E	E
Crocodylus acutus	American crocodile	E	E
Pituophis melanoleucus mugitus	Florida pine snake		SSC
Birds			
Ajaia ajaja	Roseate spoonbill		SSC
Aphelocoma coerulescens	Florida scrub-jay	T	T
Aramus guarauna	Limpkin		SSC
Caracara plancus	Audubon's crested caracara	T	T
Charadrius alexandrinus tenuirostris	Southeastern snowy plover		T
Charadrius melodus	Piping plover	T	T
Egretta caerulea	Little blue heron		SSC
Egretta thula	Snowy egret		SSC
Egretta tricolor	Tricolored heron		SSC
Eudocimus albus	White ibis		SSC
Falco peregrinus tundrius	Arctic peregrine falcon		E
Falco sparverius paulus	Southeastern American kestrel		T
Grus canadensis pratensis	Florida sandhill crane		T
Haematopus palliatus	American oystercatcher		SSC
Haliaeetus leucocephalus	Bald eagle	T	T
Mycteria americana	Wood stork	E	E
Pelecanus occidentalis	Brown pelican		SSC

Table 1. Threatened, Endangered, and Species of Special Concern in the Caloosahatchee Basin (USFWS, 1998 and FGFWFC, 1997).

Scientific Name	Common Name	Federal Status	State Status
Picoides borealis	Red-cockaded woodpecker	E	T
Phyncops niger	Black skimmer		SSC
Rostrhamus sociabilis plumbeus	Everglades snail kite	E	E
Speotyto cunicularia floridia	Florida burrowing owl		SSC
Sterna antillarum	Least tern		T
Mammals			
Blarina brevicauda shermanii	Sherman's short-tailed shrew		SSC
Felis concolor coryi	Florida panther	E	E
Felis concolor	Mountain lion	T	E
Mustela vison evergladensis	Everglades mink		T
Oryzomys palustris sanibelli	Sanibel Island rice rat	E	SSC
Podomys floridanus	Florida mouse		SSC
Sciurus niger avicennia	Big Cypress fox squirrel		T
Trichechus manatus latirostris	Florida manatee (subspecies of the West Indian manatee)	E	E
Sciurns niger shermani	Sherman's fox squirrel		SSC
Ursus americanus floridanus	Florida black bear		T
Fish			
Acipenser oxyrhynchus	Atlantic sturgeon	SSC	T
Centropomus undecimalis	Common snook	SSC	
Cyprinodon variegatus hubbsi	Lake Eustis pupfish	SSC	

T = Threatened E = Endangered SSC = Species of Special Concern
S/A = Due to similarity of appearance to endangered species.

According to Florida Fish and Wildlife Conservation Commission's *Closing the Gaps in Florida's Wildlife Habitat Conservation System* (Cox et al., 1994), the region was identified as possibly the most important area in Florida in terms of maintaining several wide-ranging species that make up an important component of wildlife diversity in the state. Furthermore, the Southwest Florida region is a unique place for the concentration of migratory species. Many birds use the area for wintering, breeding, feeding, and nesting. In addition, several species of marine fish depend on the fresh water estuary as a spawning and nursery area.

Florida Panther

The Florida panther is a large, carnivorous cat with a long tail and a short stiff pelt. Its color varies from a pale brown to rust, with dull white or buff underparts and a dark brown or blackish tail tip, ears and nose (sides). Adult male panthers reach a length of seven feet (from nose to tip of tail) and average around 120 pounds in weight. Adult female panthers are smaller, with an average weight of 75 pounds and an average length of 6 feet. The diet of the Florida panther varies geographically. Studies of South Florida populations show that white-tailed deer and feral hogs are preferred prey (Maehr et al., 1990) but they also prey on raccoons, armadillos, rabbits, birds, and small alligators (Logan et al., 1993).

The Florida panther is one of the most endangered large mammals in the world (USFWS, 1998). Currently, the population is estimated to be at 30-50 adult panthers (Cox et al., 1994). The U.S. Fish and Wildlife Service (USFWS) has developed species and habitat-level recommendations for its protection in the *Multi-Species Recovery Plan for Threatened and Endangered Species of South Florida* (USFWS, 1998). Early conservation and management efforts involved land acquisition. As this conservation effort continues, present recovery efforts are placing emphasis on two major areas: (1) protection and enhancement of the sole remaining wild population, associated habitats, and prey resources; (2) panther's historic range.

The USFWS (Logan et al., 1993) has identified panther habitat warranting preservation. Information used in this identification process included telemetry data, a forested habitat analysis, county land use plans, and land ownership patterns. Native habitat was identified using aerial photographs and verified through ground truthing. To meet the needs of the panther, habitat had to meet the following criteria: (1) must be sufficient size to support several panthers or be contiguous with occupied range; (2) must contain significant forest cover; and (3) contain few residences and few highways. This habitat was then classified as either Priority 1 or 2, based on panther use and/or habitat quality.

Priority 1 Habitats, as defined by USFWS (Logan et al., 1993), are the lands most frequently used by the panther and/or lands of high quality native habitat suitable for the panther that should be preserved first. The preservation option utilized will depend on landowner preference, agency interest, ownership patterns, fiscal limitations, and time constraints. Priority 2 Habitats are the lands less frequently used by the panther and/or lands of lower quality native habitat interspersed with intensive agriculture. These lands serve as buffer zones to urban developments and other forms of undesirable encroachment and should be preserved second. The preservation option utilized will depend on landowner preference, agency interest, ownership patterns, fiscal limitations, and time constraints. Priority 1 and 2 Habitats that lay within the Caloosahatchee River Basin are shown in **Figure 9**.

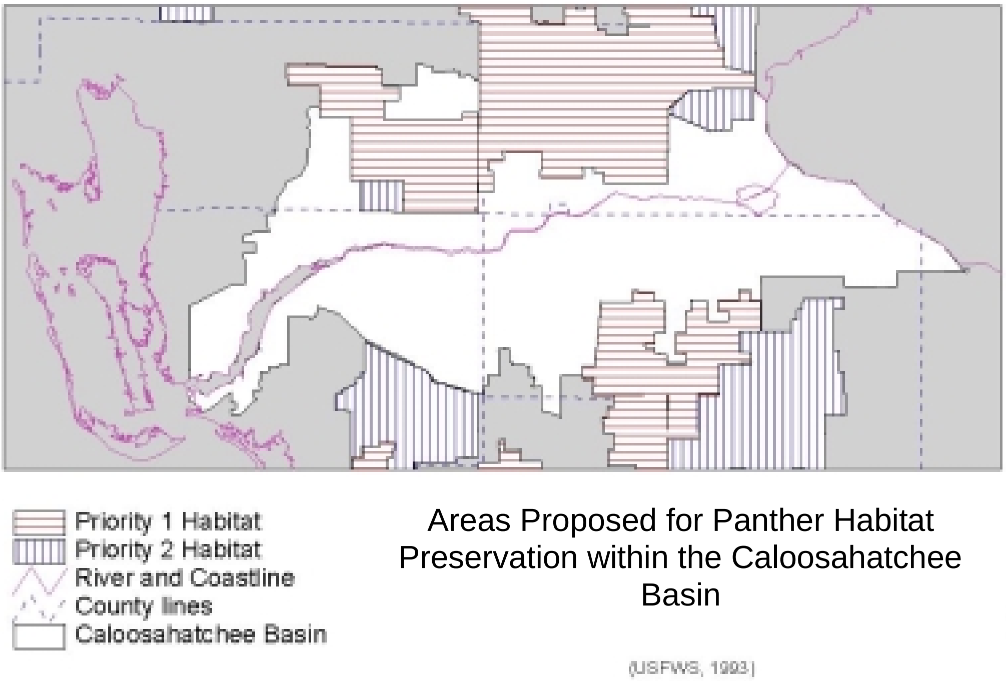


Figure 9. Priority 1 and 2 Panther Habitats.

West Indian Manatee

The West Indian manatee is one of the most endangered marine mammals in coastal waters of the United States (USFWS, 1995). United States populations are limited primarily to Florida and Georgia. The Florida population is estimated to be at least 1,856 animals (USFWS, 1995).

The West Indian manatee is a large, gray or brown, aquatic mammal. Adults average about 11.5 feet in length and weigh 2,200 pounds (USFWS, 1995). They have no hind limbs, their forelimbs are modified as flippers, and their rounded tails are flattened horizontally. The skin of a manatee is wrinkled, rubber-like, and sparsely covered with short, thick hairs. Male and female manatees are similar in size and appearance (Rathbun, 1984).

Manatees inhabit bays, estuaries, canals, rivers, and coastal areas where seagrasses and other aquatic vegetation are common. They are primarily herbivores and feed on a variety of submergent, emergent, and floating vegetation. Manatees spend about 5 hours a day feeding and may consume 4 to 9 percent of their body weight in a day (Bengtson, 1983). During cooler, winter months manatees aggregate in warm, natural springs and industrial outfalls. In the basin, the Florida Power and Light Fort Myers Plant serves as a winter aggregation site, usually with aggregates of 25 or more animals (USFWS, 1995).

Lee County Division of Natural Resource Management has developed a plan to provide the basis for countywide protection of the Florida manatee. The plan provides a basis for continued long-term enhancement of the health and welfare of manatees and their habitat. The plan contains criteria for law enforcement, habitat protection, education programs, and management of manatee-human interactions (W. Dexter Bender & Associates, Inc. 1995).

The USFWS (1995) has developed a recovery plan for the Florida manatee. The long-range goal of the plan is "restoring Florida manatees to optimum sustainable population levels under provisions of the Marine Mammal Protection Act of 1973, and maintaining them at those levels." To accomplish this, the plan establishes four objectives: (1) identify and minimize causes of manatee disturbances, injury, and mortality; (2) protect essential manatee habitat; (3) determine and monitor the status of manatee populations and essential habitat; and (4) coordinate recovery activities, monitor and evaluate progress, and update and/or revise the *Recovery Plan* (USFWS, 1995).

Eastern Indigo Snake

The eastern indigo snake is the largest nonpoisonous snake in North America. It is black, dorsally and ventrally, with a red or cream colored expansion of the chin and throat. It can reach lengths of greater than 100 inches. The eastern indigo snake frequents several habitat types including pine flatwoods, scrubby flatwoods, high pine dry prairie, tropical hardwood hammocks, edges of freshwater marshes, agricultural fields, and coastal dunes. They need a mosaic of habitats to complete their annual cycle (USFWS, 1998). Indigo snakes require sheltered refugia to shield them from cooler or desiccating conditions and are commonly found in association with gopher tortoise burrows.

The USFWS has developed species and habitat-level recommendations for the protection of the eastern indigo snake in the *Draft Multi-Species Recovery Plan* (USFWS, 1998). These include: (1) determine the distribution of the eastern indigo snake in South Florida; (2) protect and enhance existing populations of indigo snakes in South Florida; (3) protect indigo snakes in public and private lands; (4) enforce available protective measures; (5) conduct Section 7 consultations on federal activities that may affect indigo snakes; (6) implement the USFWS South Florida Ecosystem Office's Indigo Snake Guidelines for Section 7 and 10 of the Endangered Species Act (ESA) and incorporate the guidelines into permits where feasible; (7) monitor indigo snake populations; and (8) improve public attitude and behavior towards the indigo snake.

Red-cockaded Woodpecker

The red-cockaded woodpecker is a small bird with a black and white barred back and wings and white cheeks and underparts. It is approximately 8-9 inches in length and has a wingspan of approximately 17 inches, with males slightly larger than females. The red-cockaded woodpecker's range corresponds closely to the distribution of southern pines. Nesting and roosting habitat is primarily located in pine stands, or pine-dominated pine/hardwood stands, with low or sparse understory and adequate old-growth pine (USFWS, 1998).

The USFWS developed species and habitat recommendations for the red-cockaded woodpecker in the *Draft Multi-Species Recovery Plan for South Florida* (USFWS, 1998). These include: (1) determine distribution and status of red-cockaded woodpeckers; (2) develop a reserve design for red-cockaded woodpeckers; (3) protect, manage, and enhance red-cockaded woodpecker populations on public lands; (4) enforce available protective measures (Section 7 and 10 ESA); (5) conduct risk assessment analysis to determine the probability of persistence of red-cockaded woodpeckers in South Florida, given the current amount of available, suitable pineland habitat, and include pineland areas that could be restored or enhanced to become suitable habitat; (6) study the effects of habitat fragmentation due to urbanization; (7) monitor red-cockaded woodpecker subpopulations; (8) inform and involve the public; (9) prevent degradation of existing red-cockaded woodpecker habitat in South Florida; (10) prioritize areas identified in reserve design for management and acquisition; (11) protect red-cockaded woodpecker habitat on private lands though easements, acquisitions, and donations; (12) maintain adequate nesting habitat in addition to currently active clusters, to replace clusters abandoned or lost through mortality, and to provide for population expansion; (14) maintain adequate foraging habitat to support existing groups and to facilitate establishment of new territories; (15) support state land acquisition efforts; (16) prevent the loss and fragmentation of pine flatwoods within reserves; (16) restore and enhance red-cockaded woodpecker populations; (17) determine the amount of foraging habitat needed to sustain a group of woodpeckers in South Florida in both mesic and hydric pine flatwood habitats; (18) determine the potential carrying capacity for clusters of red-cockaded woodpeckers on existing public and private lands where suitable or restorable habitat exists; (19) monitor pineland habitat that is occupied by red-cockaded woodpeckers to insure public lands are managed to maintain habitat in suitable conditions for red-cockaded woodpeckers, and to assess when unmanaged areas become unsuitable; and (20) increase public awareness of pine flatwood communities.

The strategic habitat conservation areas for the red-cockaded woodpecker are shown in **Figure 10**.

Wood Stork

Wood storks are large, long-legged wading birds. They are approximately 50 inches tall, with a wing span of 60-65 inches. Their plumage is white except for some black in the wings and tail. Their head and neck are dark gray and unfeathered. The wood stork is largely colonial, nesting in rookeries and feeding in flocks. They are associated primarily with freshwater habitats for nesting, roosting, foraging, and rearing (USFWS, 1998).

Loss or degradation of wetlands in central and southern Florida is one of the principle threats to the wood stork. The USFWS has developed species and habitat-level recommendations for their protection in the *Draft Multi-Species Recovery Plan of South Florida* (USFWS, 1998). Recommendations include: (1) preventing degradation of nesting, foraging, and roosting habitats; (2) protecting and enhancing wood stork protection through provisions of Section 7 ESA; (3) determining the foraging ecology and behavior of wood storks; (4) protecting wood storks from mercury and other

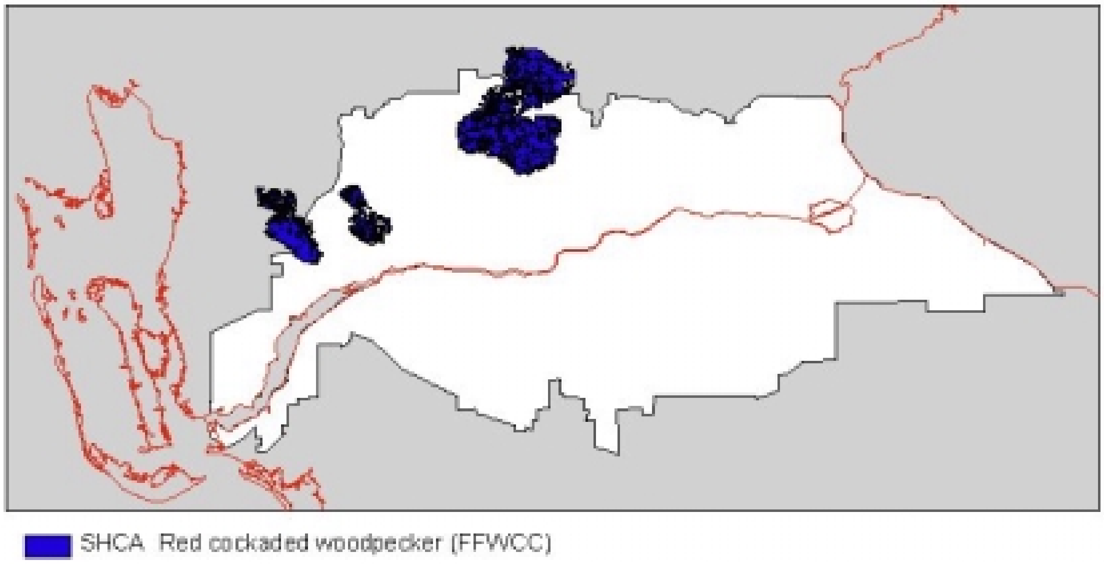


Figure 10. Strategic Habitat Conservation Areas for the Red-Cockaded Woodpecker.

contaminants; (5) prioritizing habitats that need protection; (6) assisting private landowners in managing for wood storks by providing Best Management Practices, incentives, or management plans; (7) developing consistent with the Habitat Management Guidelines for Wood Storks (Ogden, 1990); (8) utilizing existing wetland regulatory mechanisms to protect foraging habitat in South Florida (federal and state permitting actions); (9) developing Habitat Conservation Plans; (10) adaptive restoration and enhancement of suitable habitat; (11) enhancing breeding and wintering activities of wood storks in South Florida; (12) determining the effects of natural and human-caused hydrologic events on ecology of the wood stork prey base; and (14) acquire land identified as important to wood storks.

The strategic habitat conservation areas for wading birds in general are shown in **Figure 11**.

Florida Scrub Jay

The Florida scrub jay is a subspecies of Scrub Jay, which is widespread in the western U.S. and Mexico. It is a blue and gray crestless jay approximately 11-12 inches in length. The Florida scrub jay's habitat is restricted to scattered, often small, isolated patches of sand pine scrub, xeric oak scrub, and scrubby flatwoods in peninsular Florida. Optimal scrub jay habitat is dominated by shrubby scrub live oaks, myrtle oaks, or scrub oaks from 3-10 feet tall covering 50-90% of the area; bare ground or sparse vegetation less than 6 inches tall covering 10-50% of the area; and scattered trees, with no more than 20%

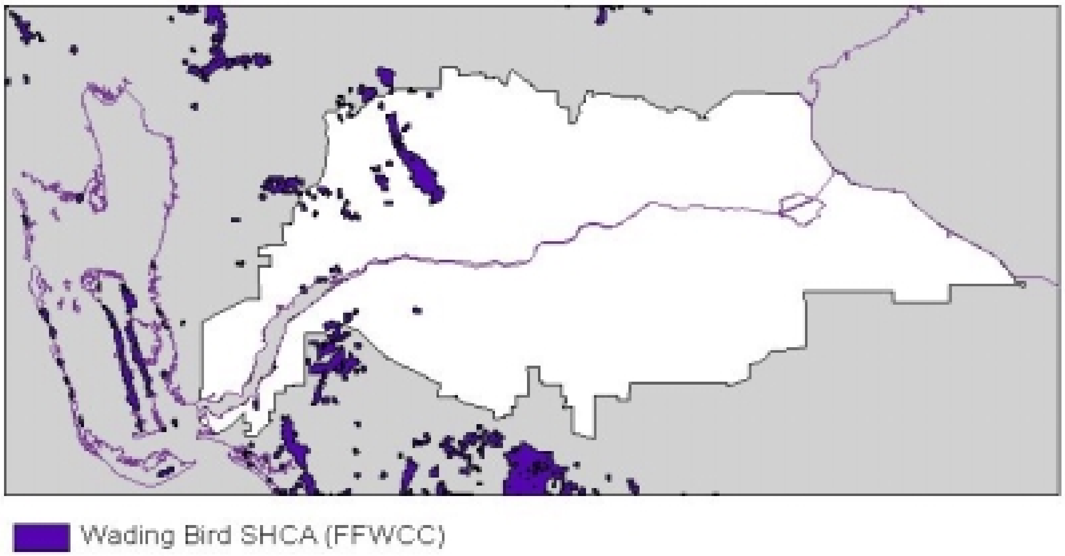


Figure 11. Strategic Habitat Conservation Areas for Wading Birds.

canopy cover (information from Florida Fish and Wildlife Conservation Commission (FFWCC)).

The original range of the jay is estimated at 7,000 square miles but has been reduced considerably by suburban development and conversion of scrub habitats to agricultural uses. Due to this extensive habitat loss and the elimination of the scrub jays from much of its formal range, both USFWS and FFWCC now legally protect them as a threatened species.

The USFWS has developed recommendations in the *Multi-Species Recovery Plan for South Florida* (USFWS, 1998) for the protection of the Florida scrub jay. These include: (1) determine the distribution of Florida scrub jays and status of scrub habitat in South Florida; (2) maintain scrub jay habitat and distribution data in a GIS database; (3) protect and enhance Florida scrub jay populations; (4) develop a reserve design for Florida scrub jays in South Florida using landscape maps, GIS and spatially-explicit population models; (5) protect, manage, and enhance Florida scrub jay populations on public lands; (6) protect, manage, and enhance Florida scrub jay populations on privately-owned lands; (7) enforce available protective measures (Sections 7 and 10 ESA); (8) conduct risk assessment analysis to determine the probability of persistence of the scrub jay in South Florida, given the current amount of suitable scrub habitat, as well as potentially restorable scrub habitat; (9) study the effects of habitat fragmentation due to urbanization; (10) monitor scrub jay populations; (11) inform and involve the public; (12) prevent degradation of existing scrub habitat; (13) prioritize areas identified in reserve design for acquisition and donations; (14) protect scrub jay habitat on private lands through easements, acquisitions, and donations; (15) continue state and federal land acquisition efforts; (16) maintain suitable habitat for scrub jays; (17) prevent loss or fragmentation of scrub habitat within scrub jay reserves; and (18) monitor scrub habitat that is occupied by scrub jays to insure public lands are managed to maintain scrub in suitable conditions for scrub jays, and to assess when unmanaged areas become unsuitable for scrub jays.

The strategic habitat conservation areas for the Florida scrub jay is shown in **Figure 12**.

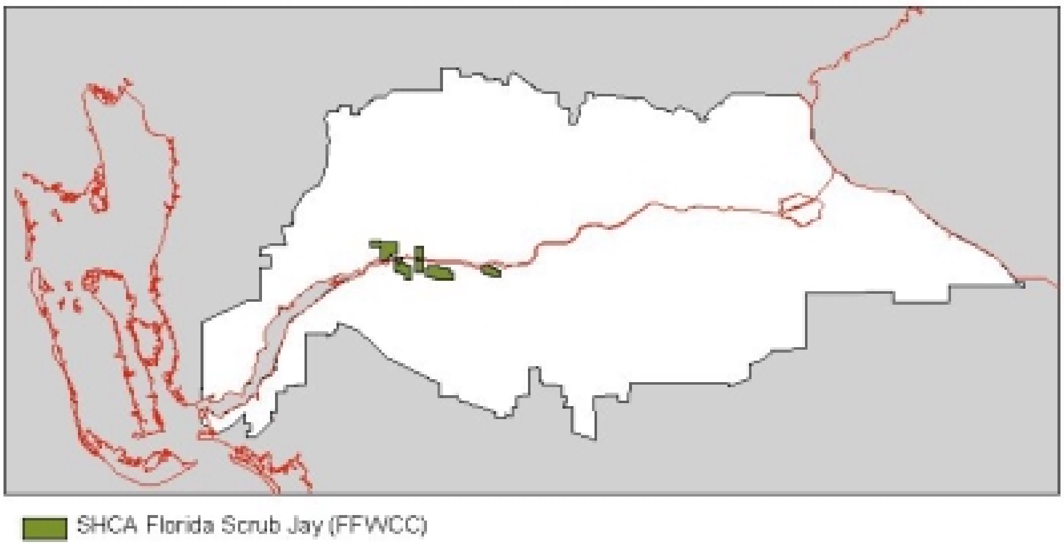


Figure 12. Strategic Habitat Conservation Areas for the Florida Scrub Jay.

WATER NEEDS

Wetlands

Maintaining appropriate hydrology (water levels and hydroperiod) is the single most critical factor in maintaining a viable wetland ecosystem (Duever, 1988; Mitch and Gosselink, 1986; Erwin, 1991). Rainfall, along with associated ground water and surface water inflows, is the primary source of water for the majority of wetlands in the Caloosahatchee Basin. The natural variation in annual rainfall makes it difficult to determine what the typical water level or hydroperiod should be for a specific wetland system. Because wetlands exist along a continuous gradient, changes in the hydrologic regime may result in a change of the position of plant and animal communities along the gradient. The effects of hydrologic change are both complex and subtle. They are influenced by and reflect regional processes and impacts as well as local ones (Gosselink et al., 1994).

Studies of Southwest Florida wetland communities indicate that species composition and community type are largely determined by water depth and hydroperiod (Carter et al., 1973; Duever, 1984; Duever et al., 1986). Some wetlands contain water depths of 3 feet or more and are inundated year round, while other communities are characterized by saturated soils or water depths of less than a few inches that inundate the land for relatively short periods of time during the wet season. Wetland flora and fauna adapted to deep water and long periods of inundation are generally not well adapted to shallow water or a shortened hydroperiod. Complete drainage of a wetland severely alters wetland community organization and species composition. Partial drainage of wetlands can be caused by ground water withdrawals in adjacent upland areas. These withdrawals effectively lower underlying water tables and "drain" wetlands (Rochow, 1989). Drainage facilities such as canals and retention reservoirs constructed near wetlands have a history of draining and reducing hydroperiods of South Florida wetlands (Erwin, 1991). A major concern of reduced water depths and shortened hydroperiods within wetlands is the invasion of exotic plants such as melaleuca and Brazilian pepper.

Rainfall, along with associated ground water inflows, is the primary source of water for the majority of wetlands in the basin. Rainfall in South Florida is highly variable. Although the region has a distinct wet and dry season, the timing and amount of rainfall that falls upon a particular wetland varies widely from year to year. As a result, wetland hydroperiod also varies annually. Hydroperiod information collected from a wetland during a series of wet years may vary considerably from data collected during a dry year. This wide variation in annual rainfall makes it difficult to determine what the appropriate water level or hydroperiod should be for a specific wetland ecosystem. Determining appropriate water level or hydroperiod conditioned for a wetland often requires a data collection effort that spans a significant period of record. Hofstetter and Sonenshein (1990) suggest alterations that shorten hydroperiods may be detectable within 8 to 10 years.

Uplands

The water supply needs of upland plant communities are not well known. It is assumed that forest and herbaceous plant vegetation utilize the upper 6 to 10 feet of the surficial aquifer. Flatwoods are the dominant upland habitat within the basin. These plant associations are characterized by low, flat topography and poorly drained, acidic, sandy soils. In the past this ecosystem was characterized by open pine woodlands and supported frequent fires (Myers and Ewel, 1990). Three factors including fire frequency, soil moisture, and hydrology, play important roles in maintaining plant community structure and function and are also considered important as determinants of the direction of plant community succession. Fire, more than any other factor influences the structure and composition of upland plant communities.

Fire, under natural conditions, maintains flatwoods as a stable and essentially nonsuccessional plant association. However, when drainage improvements, construction of roads, or other fire barriers alter the natural frequency of fire, flatwoods can succeed to several other plant community types. The nature of this succession depends on soil characteristics, hydrology, available seed sources or other local conditions (Myers and Ewel, 1990). The hydrology of upland plant communities varies with elevation and topography. Seasonal variations, as well as local withdrawals from ground water, play an important role in determining the type of upland vegetation that will develop.

Wildlife

In South Florida the dominant physical factors which influences the species composition, distribution, and abundance of wildlife are the annual pattern of rainfall, water level fluctuations, and fire, as well as occasional hurricanes, frosts, and freezes. Biological factors such as predation, competition and feeding habits also play important roles in configuring wildlife communities.

Alterations in water depth and/or hydroperiod that result in changes to vegetative composition densities and diversity may lead to the degradation of fish and wildlife habitat. One of the causes of melaleuca infestation is a decrease in water table levels which, when a seed source is present, can result in monotypic stands of tightly packed trees that have the potential to cause a localized decrease in biodiversity.

Wetland vegetative productivity usually exceeds that of other habitat types. Reduction in size of a wetland reduces food production at the bottom of the food chain. Alterations of the seasonal wet and dry pattern can also cause impacts. The life cycle of many species are tied to this cycle. Wood storks, for example, are unable to successfully fledge their young without the dry season concentration of food. Anything that interferes with the cycle, too much water in the dry season or not enough in the wet season, tends to reduce fish and wildlife populations (University of Florida, Center for Government Responsibility, 1982).

Flooding of wetlands during the summer months initiates the production of aquatic plants such as attached algae (periphyton) and macrophyte communities. Small fish and invertebrates consume these plants. Maximum numbers of fish and invertebrates occur near the end of the wet season. As marsh water levels decline during the dry season, these organisms are concentrated into smaller and smaller pools of water where they become easy prey for wading birds and other species of wildlife. Fish and invertebrates are the major dietary components of South Florida wading and water bird populations. Wading bird nesting success is highly dependent upon the natural seasonal fluctuations in hydroperiod of these marsh systems and the concentration of food resources. Kahl (1964) and SFWMD (1992) link the nesting success of wood storks and white ibis to the hydrologic status of regional wetland systems.

PROTECTION OF NATURAL RESOURCES

The SFWMD protects and enhances natural resources through its wetland policies and rules, wellfield location criteria, wetland buffers, wellfield monitoring, wetland mitigation banking, surface water planning, and land acquisition programs.

Wetland Policies

The SFWMD undertakes regulatory control measures to prevent adverse impacts to wetlands from ground water withdrawals by incorporating numerous state laws into its consumptive use permitting process, which limit drawdowns beneath wetlands. The obligation to leave enough water in natural areas to maintain their functions and protect fish and wildlife is central to water supply planning.

The *State Comprehensive Plan* (Chapter 187, F.S.) states as a goal that:

> Florida shall maintain the functions of natural systems and the overall present level of surface and ground water quality.

The same document lists as a policy:

> Reserve from use that water necessary to support essential nonwithdrawal demands, including navigation, recreation, and the protection of fish and wildlife.

The Water Resources Act of 1972 (Chapter 373, F.S.) states:

> The minimum water level shall be the level of ground water in an aquifer and the level of surface water at which further withdrawals would be significantly harmful to the water resources of the area. The SFWMD's Water Supply Policy Document affirms that "the SFWMD recognizes the state policies which establish priority protection of the water supply required to maintain and enhance healthy natural systems.

The extent to which wetland preservation conflicts with water supply development depends greatly on the approach of that development. For example, options that increase water storage, relieve the conflict between wetlands and human development, as does appropriate location and design of wellfields or the use of surface water. The challenge is to accept wetland protection as a constraint and then come up with the most reliable and cost-effective water supply strategy. The water needs of wetlands must be met. The plan's approach at this time is to meet the intent of specific flows and levels for isolated inland wetlands, and to protect them against changes in existing water regimes.

Wetland Protection Criterion

In order to assess the potential harmful impacts of cumulative water use on the environment and ground water resources using the ground water modeling tools, the potential impacts must be defined in terms of water levels and duration and frequency of drawdowns. These water levels are referred to as resource protection criteria. The resource protection criteria are guidelines used to identify areas where there is potential for cumulative water use withdrawals to cause harm to wetlands and ground water resources. Areas where simulations show the resource protection criteria are exceeded during the selected level of certainty are areas where the water resource may not be sufficient to support the projected demand under the constraints.

Resource protection criteria in this plan are designed to prevent harm to the resources up to a 1-in-10-drought event. These criteria are not intended to be a minimum flow and level. For drought conditions greater than a 1-in-10 event, it may be necessary to decrease water withdrawals to avoid causing significant harm to the resource. Water shortage triggers, or water levels at which phased restrictions will be declared under the SFWMD's water shortage program, can be used to curtail withdrawals by water use types to avoid water levels declining to and below a level where significant harm to the resource could potentially occur.

The wetland protection criterion is defined as follows: Ground water level drawdowns induced by cumulative pumping withdrawals in areas that are classified as a wetland should not exceed one-foot at the edge of the wetland for more than 1 month during a 12-month drought condition that occurs as frequently as once every 10 years. For planning purposes, this criterion was applied to surficial aquifer drawdowns in areas that have been classified as a wetland according to the National Wetlands Inventory. For the purpose of this plan, the existing one-foot wetland drawdown criteria will be used.

Section 3.3, *Environmental Impacts, of the SFWMD's Basis of Review for Water Use Permit Applications* (BOR, 1997), requires that withdrawals of water must not cause adverse impacts to environmental features sensitive to magnitude, seasonal timing and duration of inundation. Maintaining appropriate wetland hydrology (water levels and hydroperiod) is scientifically accepted as the single most critical factor in maintaining a viable wetland ecosystem (Duever, 1988; Mitch and Gosselink, 1986; Erwin, 1991). Water use induced drawdowns under wetlands potentially affect water levels, hydroperiod, and the arial extent of the wetland. A guideline of no greater than one-foot of drawdown at the edge of a wetland after 90 days of no recharge and maximum day withdrawals is used currently for consumptive use permitting (CUP) purposes to indicate no adverse impacts. Wetlands for CUP purposes are delineated using the statewide methodology as described in Chapter 62-340, F.A.C.

The wetland protection criteria used in this plan are intended to be consistent with the guidelines currently used in the CUP program. Modeling studies conducted in conjunction with the SFWMD's *Lower West Coast (LWC) Water Supply Plan* and the CWMP suggested that the withdrawals associated with different use types might have different drawdown impacts at wetlands. It was concluded that for public water supplies, the 90-day no recharge guideline currently used was equivalent to five months of maximum day pumpage in models with 1-in-10 year drought conditions and recharge.

Wellfield Location

Locating wellfields away from wetlands is an approach that can reduce local environmental effects but is not always easy to implement. Often the choice is reduced to either locating the wellfield in undeveloped areas with environmentally sensitive wetlands or in developed uplands where the potential for wellfield contamination is a serious concern.

Wetland Buffers

Another approach involves using man-made lakes or reservoirs as a buffer between wellfields and natural wetland systems. The water in these lakes acts as a buffer by managing the local water table at a sufficient level to avoid impacts to nearby wetlands. The surface water that is available in these lakes or reservoirs can also be used to supplement ground water withdrawals.

Wellfield Impact Monitoring

The SFWMD's Resource Assessment Division began a research program in 1995 to support development of wetland drawdown criteria. This project involves long-term monitoring of wellfields and wetland systems, including some systems in the CWMP planning area. The research project is broken down into three phases.

Phase I consists of: (1) a literature review to determine if sufficient information is present to support existing drawdown criteria or to recommend new criteria; (2) ground water modeling; and (3) a scientific wetland expert workshop. This phase was completed November 1995.

The objectives of Phase II were to: (1) determine the extent and severity of impacts, if any, caused by ground water withdrawals under present and past drawdown criteria; and (2) identify wetland sites throughout the SFWMD for well installation and hydrobiological monitoring. The completion date for Phase II was December 1996.

Phase III has two main objectives: (1) implement long-term hydrobiological monitoring at wetlands located along a gradient of drawdown in selected study sites; and (2) test hypotheses regarding: (a) the effects of ground water drawdowns on wet season biological productivity; (b) the dependence of surface soil moisture on the dry season water table position; (c) differences in ecosystem structure and function between wetlands subject to different amounts of drawdown; (d) the effects of local versus regional calibration of ground water models used in the permit application process; and (e) symptoms of impact observed during drought.

Presently, two years of data have been collected and analyzed. This information is in draft form in *Hydrology of Isolated Wetlands of South Florida: Results of 1997-1998 Monitoring and Data Analysis and Guidance for Developing Wetland Drawdown Criteria* (Shaw and Huffman, 1999). Biological studies will facilitate the characterization of biotic communities of the selected wetland sites and development of nondestructive long-term monitoring methods. To date, inventories of plant, fish, aquatic insect, bird, moss, algae, and amphibian populations have been conducted. Various sampling methods are presently under investigation for incorporation into a long-term monitoring effort.

Monitoring wetlands adjacent to wellfields ensures that withdrawal impacts are detected. Steps can then be taken to limit further impacts. Long-term monitoring of wetlands adjacent to wells provides documentation of impacts to wetlands that occur over time.

The hydrologic and biologic consequences of ground water withdrawal from wellfields in the Northern Tampa Bay region have been documented by the Southwest Florida Water Management District (SWFWMD). After long-term monitoring of wells and wetland systems, SWFWMD concluded that adverse impacts are especially evident in areas where ground water modeling of withdrawals indicates a drawdown of one-foot or more.

The type of impacts noted for marsh and cypress wetlands were as follows:

- Extensive invasion of weedy upland species
- Destructive fires
- Abnormally high treefall
- Excessive soil subsidence/fissuring
- Disappearance of wetland wildlife

The SWFWMD ground water modeling has also shown that it may take one to two decades for the full effect of wellfield pumpage to be realized. Therefore, actual water levels in newer wellfields, or in wellfields currently not pumping at their maximum permitted levels, could become lower in the future. For these and other reasons, SWFWMD suggests that continued environmental monitoring will be necessary to ensure that Florida's wetlands are adequately protected (Rochow, 1984).

Wetland Mitigation Banking

Wetland mitigation banking is a relatively new natural resource management concept, which provides for the advanced compensation of unavoidable wetland losses due to development. The Florida Environmental Reorganization Act of 1993 directed the water management districts (WMDs) and the Florida Department of Environmental Protection (FDEP) to participate in and encourage the establishment of public and private regional mitigation areas and mitigation banks. The act further directed the WMDs and FDEP to adopt rules by 1994, which led to the state's mitigation banking rule (Chapter 62-342, F.A.C.), becoming effective January 1994. In 1996, House Bill 2241 further developed this program by providing for the acceptance of monetary donation as mitigation in SFWMD and FDEP endorsed off-site regional mitigation areas. The bill clarified service area requirement credit criteria and release schedules, assurances, and provisions that apply equally to public and private banks. As a result, the SFWMD and FDEP will adopt rules to implement these provisions. Wetland mitigation banking does not apply to water use related impacts.

Surface Water Improvement and Management

Under the provisions of the Surface Water Improvement and Management (SWIM) Act, the SFWMD was required to develop and implement a SWIM plan to preserve, protect, and restore Lake Okeechobee. *The Lake Okeechobee SWIM Plan* was enacted in 1989 and had its second update in August 1997. The environmental element recognized that adverse impacts to the Caloosahatchee Estuary occur when regulatory releases are made through C-43 Canal for lake flood protection purposes. Large, unnatural freshwater releases from the lake through the C-43 to the Caloosahatchee Estuary alter the estuarine salinity gradient and transport significant quantities of sediment to the estuary. Biota within the Caloosahatchee Estuary, and near-shore seagrass beds can be negatively affected by these high volume discharges.

Minimum Flows and Levels

The purpose of establishing Minimum Flows and Levels (MFLs) is to avoid diversions of water that would cause significant harm to the water resources or ecology of an area. The Florida Legislature has mandated that all water management districts establish MFLs for surface waters and aquifers within their jurisdiction. Section 373.042(1) defines the minimum flow as "the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area." It further defines the minimum level as the "level of ground water in an aquifer and the level of surface water at which further withdrawals would be harmful to the water resources of the area." The SFWMD is further directed to use the best available information in establishing a minimum flow or a minimum level.

The overall purpose of Chapter 373 is to ensure the sustainability of water resources of the state (Section 373.016, F.S.) To carry out this responsibility, Chapter 373 provides the SFWMD with several tools, with varying levels of resource protection standards. MFLs play one part in this framework. Determination of the role of MFLs and the protection that they offer, versus other water resource tools available to the SFWMD, are discussed below.

The scope and context of MFLs protection rests with the definition of significant harm. The following discussion provides some context to the MFLs statute, including the significant harm standard, in relation to other water resource protection statutes.

Sustainability is the umbrella of water resource protection standards (Section 373.016, F.S.). Each water resource protection standard must fit into a statutory niche to achieve this overall goal. Pursuant to Parts II and IV of Chapter 373, surface water management and consumptive use permitting regulatory programs must prevent harm to the water resource. Whereas water shortage statutes dictate that permitted water supplies must be restricted from use to prevent serious harm to the water resources. Other protection tools include reservation of water for fish and wildlife, or health and safety (Section 373.223(3)), and aquifer zoning to prevent undesirable uses of the ground water (Section 373.036). By contrast, MFLs are set at the point at which significant harm to the water resources, or ecology, would occur. The levels of harm cited above, harm, significant harm, and serious harm, are relative resource protection terms, each playing a role in the ultimate goal of achieving a sustainable water resource.

Where does the significant harm standard lie in comparison to the consumptive use permitting and water shortage standards? The plain language of the standards of harm versus significant harm, although undefined by statute, implies that the minimum flow or level criteria should consider impacts that are more severe than those addressed by the consumptive use permitting harm standard, but less severe than the impacts addressed by the serious harm water shortage standard. MFLs for the Caloosahatchee Estuary will be established no later than December 2000 and incorporated into the *LWC Water Supply Plan.*

Section 373.0421 requires that once the MFL technical criteria have been established, the water management districts develop a prevention or recovery strategy for those water bodies that are expected to exceed the proposed criteria. It is possible that the proposed MFL criteria cannot be achieved immediately because of the lack of adequate regional storage. Pending congressional authorization of the Restudy, these storage shortfalls may be resolved through construction of facilities that will increase the region's storage capacity. Operational strategies, including supplementing flow to the C-43 Canal during the dry season with water from Lake Okeechobee, will be evaluated.

The SFWMD's effort in managing flows to the Caloosahatchee Estuary has focused on ecological criteria. Oysters and SAV have been selected as key indicators of healthy estuarine systems because they provide food and/or habitat for much of the estuarine community. Accordingly, the SFWMD is evaluating ways to establish healthy, self-perpetuating populations of these organisms in the Caloosahatchee Estuary. Hydrodynamic salinity models have been developed which can predict salinity regimes in estuaries based on freshwater inflows. Geographic Information System (GIS) coverages (including substrate type, shoreline features, and current SAV and oyster distributions) are being developed for the estuary. Comparing these coverages with salinity model output will help refine where oysters and SAV could occur once flow management strategies are in place. Optimization models are being used to help predict how much water must be held back in the basin, as well as to determine schedules for releasing the stored water to meet the salinity requirements of oysters and SAV. Ultimately this information will be coupled with basin models to evaluate specific "in basin" management scenarios needed to meet the inflows necessary to maintain healthy SAV and oyster community requirements.

The USACE in cooperation with the SFWMD has evaluated environmental and economic impacts associated with proposed regulation schedules for Lake Okeechobee. The regulation schedule dictates the water levels within the lake and regulatory discharge strategies to maintain these levels. This study was completed in 1999.

Two water bodies within the LWC Planning Area are on the SFWMD's priority list for establishment of MFLs: the Caloosahatchee Estuary and the LWC aquifer system. Both of these are anticipated to be completed by the end of 2000. Additional information on these is provided in the Planning Document.

Chapter 3
WATER SOURCE OPTIONS

BACKGROUND

The goal of the *Caloosahatchee Water Management Plan* (CWMP) is to assess the present and future water supply needs for urban and agricultural users, and develop a plan to meet those needs, while restoring, preserving, and protecting the ecosystem of the Caloosahatchee Basin, including the Caloosahatchee Estuary. To achieve this goal, it was necessary to evaluate the water resources potential of the Caloosahatchee Basin. Specifically, it was necessary to evaluate the potential of meeting current and future environmental, agricultural, and urban water needs of the basin and estuary through the combined use of surface water and, where necessary and available, ground water.

Previous studies of the Caloosahatchee Basin and similar watersheds in South Florida have shown that abundant water supplies are available during times of the year. During the wet season, a significant amount of runoff occurs and flows to the estuary. During the dry months, when lower flows are occurring, human demands are highest. Due to extensive drainage works previously constructed and other conditions, the flows to the estuary during the wet season are often significant and have been identified as having an adverse affect on the functions of the estuary. A strategy for storing high flows during the wet months to meet demands during the dry months was identified as a means of restoring the function of the estuarine system while meeting other demands.

A critical component of this analysis was the projection of future demands. Numerous iterations of the 2020 land use were produced. This was used to calculate the 2020 demand using the Agricultural Field Scale Irrigation Requirements Simulation model (AFSIRS). The MIKE SHE model calculates demand internally and this compares favorably with the demands from the AFSIRS model. The revised demands were provided to planning staff to be input into the South Florida Water Management Model (SFWMM) as part of the development of the *Lower East Coast (LEC) Regional Water Supply Plan*. As part of this plan, several storage options (components) were investigated using the MIKE SHE model.

Water source options are options that make additional water available from existing or new sources, such as reservoirs and Aquifer Storage and Recovery (ASR), wastewater reuse, and conservation. This chapter discusses options that increase surface water availability. Because this water management plan is directed to the Caloosahatchee River and the majority of water use in the basin is surface water, the options outlined in the CWMP focus on surface water source options.

SURFACE WATER STORAGE

Surface water can be stored by pumping surface water runoff and ground water seepage into regional storage systems during periods of excessive rainfall to provide additional water supply and flood protection. The capture of surface water runoff and ground water seepage in canals of the primary water management system, and storage of these waters in existing or new surface water reservoirs or impoundments, provides an opportunity to increase the supply of fresh water during subsequent dry periods. The primary problems associated with surface water storage are the expense of constructing and operating large capacity pumping facilities, the cost of land acquisition, appropriate treatment costs, the availability of suitable locations, and the high evaporation rates of surface water bodies. **Table 2** presents surface water storage cost estimates.

Table 2. Surface Water Storage Costs.

Reservoir Type	Construction Cost	Engineering Design Cost $/Acre	Construction/ Administration $/Acre	Land $/Acre	Operations and Maintenance $/Acre
Minor Reservoir	2,842	402	318	3,000-6,000	118
Major Reservoir	7,980	904	451	3,000-6,000	105

Note: These estimates are taken from the LWC Water Supply Plan.

There are several surface water impoundments included in the Restudy. The components for which the largest surface water reservoirs are planned are north of Lake Okeechobee storage, Everglades Agricultural Area (EAA) storage, Caloosahatchee storage, and St. Lucie storage. The maximum depth of the impoundments contained within the Restudy ranges from 4 feet to 12 feet. General geologic information indicates that the surficial soils throughout South Florida are not very deep and are underlain by very permeable shallow aquifers. Therefore, core borings and field permeability tests will have to be executed in all of these areas to determine the thickness and permeabilities of the surficial soils. If it is determined that the surficial soils do not have low enough permeabilities to hold water in the impoundments, alternative approaches to modifying the bottom of the impoundment areas will be necessary. These alternatives are to modify the in-situ materials by adding either a clay liner or geotextiles (High Density Polyethylene, HDPE) to the existing soils to decrease permeability.

Creating a low-permeability liner by modifying the in-situ materials is an economical alternative. If the in-situ materials are sandy, this could be accomplished by mixing a small percentage by weight of dry bentonite with the sand. When the bentonite-sand mixture becomes moist, it will create a low-permeability liner for the impoundment area.

If the in-situ materials are limestone, the upper two feet of limestone could be scraped by bulldozers, processed in-place by crushing, and then compacted by steel-wheeled vibratory rollers to create a low-permeability liner. The processed and compacted in-place limestone may, itself, have an appropriate permeability range to provide for the retention of water while allowing some of the water to recharge the surficial aquifer from the impoundment. If necessary, materials such as bentonite or Portland cement could be added to the limestone to lower the permeability of the processed and compacted limestone liner.

The costs to install a HDPE liner vary depending on the depth of the area to be lined. For depths of 20 feet or less, the liner will cost approximately $0.20 per square foot installed, whereas it will cost about $0.50 per square foot installed for depths between 20 and 40 feet. Eighteen inches of fill cover will cost about $3.00 per cubic yard and clearing, grubbing, and leveling (does include fill) will cost approximately $1,000 per acre. These cost estimates were based on a combination of manufacturer information, consultant experience, Everglades Construction Project (ECP) experience, and *Means Estimating Guide*.

AQUIFER STORAGE AND RECOVERY

Aquifer Storage and Recovery (ASR) is defined as the underground "storage" of injected water in an acceptable aquifer during times when water is available, and the subsequent "recovery" of this water when it is needed. Simply stated, the aquifer acts as an underground reservoir for the injected water, reducing the water loss to evaporation. Sources of injection water could include treated and untreated ground water and surface water, and reclaimed water.

ASR has been in use in the United States since 1968, and there are now numerous ASR facilities throughout the country. In South Florida, ASR is used to store surplus freshwater during rainy summer season, for later use during the dry winter season.

Most existing ASR facilities are associated with water treatment plants and store treated drinking water. These facilities range in capacity from 1 to 15 million gallons of water per day (MGD). Also, a number of raw (untreated) ground water ASR facilities are currently under construction or being tested in Florida. Although a number of possible sources of water are available for use with ASR (treated surface and ground water, raw surface and ground water, and reclaimed water), the technology itself is the essentially the same for each source.

Large reservoirs could be used to capture and store surface water runoff until needed, or the captured water could be stored underground in deep aquifers using ASR technology. Land costs and seepage and evapotranspiration losses make the use of reservoirs generally more expensive and less efficient than storing the water underground using ASR technology.

Aquifer Storage and Recovery Costs

Estimated project costs for ASR consisting of a 900-foot, 16-inch well, with two monitoring wells using treated water are shown in **Table 3**. One system uses pressurized water from a utility; whereas the second ASR system uses unpressurized treated water, thus requiring pumping equipment as part of the system cost. Using the assumptions that the capital costs are amortized at 8 percent over 20 years, that the water recovery efficiency is 75 percent, and 100 days of recovery at the daily recovery capacity, the costs translate into costs of $.23 to $.27 per thousand gallons. However, utilities implementing ASR systems may incur additional costs for surface facilities, such as piping, storage, and rechlorination. Other available data indicate that "typical unit costs for water utility ASR systems now in operation tend to range from $200,000 to $600,000 per MGD of recovery capacity" (Pyne, 1995). At the same annual recovery rate used above (100 days at the daily recovery capacity), the costs per thousand gallons recovered would be $.30 to $.70 per thousand gallons. These systems have well capacities from 0.3 to 3 MGD and store treated water. Savings in treatment system costs are likely to be substantial when the ASR system offsets the need for capacity to meet peaks in demands. Water for ASR should be reflected in the water use permit. The costs related to ASR in the planning area are currently being revised. Until this information becomes available, the most recent available cost information is provided in **Table 3**.

Table 3. Aquifer Storage and Recovery System Costs.[a]

System	Well Drilling Cost	Equipment Cost	Engineering Cost	Operations and Maintenance Cost (per 1,000 gallons)	Energy Cost (per 1,000 gallons)
Treated Water at System Pressure	$250,000	$40,000	$450,000	$.005	$.08
Treated Water Requiring Pumping	$250,000	$125,000	$500,000	$.008	$.08

a. Costs are based on a 900 foot, 16-inch well, with two monitoring wells using treated water.
Note: These estimates are taken from the LWC Water Supply Plan.

Existing ASR Facilities

There are many ASR facilities in operation in the United States, including New Jersey, Nevada, California, and Florida. In Florida, there are numerous ASR projects in operation, under construction, or in the permitting phase (**Table 4**). Operational facilities include: Manatee County, Peace River, Cocoa, Port Malabar, and Boynton Beach. All but the Marco Island facility use treated water. Marco Island uses raw surface water from a borrow pit. Lee County has completed their ASR well and is in the testing phase. Bonita Springs is in the permitting/design phase while several other entities are evaluating the feasibility of ASR.

Table 4. ASR Wells in Operation or Under Feasibility/Construction/Testing in Florida.

ASR Facility	Water Source	Capacity	Status
Peace River / Manasota Regional Water Supply Authority	Treated surface water	8 MGD	Operating/Expansion
Manatee County	Treated surface water	5 MGD	Operating/Expansion
City of Cocoa	Treated ground water	8 MGD	Operating/Expansion
Palm Bay (Port Malabar)	Treated ground water	1 MGD	Operating
Marco Island (Florida Water Services)	Raw surface water (with filtration & chlorination)	1 MGD	Operating (expanding to 6 MGD)
City of Boynton Beach	Treated ground water	1.5 MGD	Operating
City of Tampa	Treated surface water	1.5 MGD	Operating/Expansion
Lee County Utilities	Treated ground water	---	Cycle testing
Miami-Dade Water and Sewer Dept. West Wellfield	Raw ground water	15 MGD	Construction & testing
Miami-Dade Water and Sewer Dept. Southwest Wellfield	Raw ground water	10 MGD	Construction
City of Punta Gorda	Treated surface water	---	Construction
Broward County	Raw ground water	3 MGD	Testing
City of Delray Beach	Treated ground water	3 MGD	Under construction
Palm Beach County System 3	Treated ground water	2 MGD	Under construction
City of West Palm Beach	Treated surface water	3 MGD	Constructed, in testing
City of Sunrise	Treated ground water	2 MGD	Construction & testing
Northwest Hillsboro County	Reclaimed water	6 MGD	Under construction
Fort Lauderdale	Raw ground water	2 MGD	Construction & testing
Bonita Springs Utilities	Treated ground water	1 MGD	Permitting/design
Bonita Springs Utilities	Raw surface water (filtration/chlorination)	2 to 3 MGD	Permitting/design
Englewood Water District	Reclaimed water	1 to 2 MGD	Permitting/design
Manatee County	Reclaimed water	10 MGD	Permitting/design
City of St. Petersburg	Reclaimed water	1 to 2 MGD	Feasibility/permitting
Marco Island	Reclaim/treated surface water	TBD	Feasibility
Lehigh Acres (Florida Water Services)	Reclaimed water	TBD	Feasibility
City of Tampa	Raw surface water (with filtration & chlorination)	1 to 3 MGD	Feasibility
City of Fort Myers	Treated surface water	TBD	Feasibility
South-Central Hillsboro County	Reclaimed water	12 MGD	Feasibility
Sarasota County	Reclaimed water	---	Feasibility
City of Sarasota	Reclaimed water	---	Feasibility
City of Bradenton	TBD	TBD	Feasibility
St. Johns River WMD (6 sites)	Treated surface/ground water and reclaimed water	---	Feasibility
Naples	Treated ground water	---	---
Florida Keys Aqueduct Authority (Marathon)	Treated ground water	0.5 MGD	Not in operation
South Florida WMD Demonstration Project (Test well)	Untreated surface water	---	Not in operation
South Florida WMD Hillsboro Canal ASR Pilot Project	Untreated ground water	20 to 30 MGD	Geologic well
South Florida WMD Lake Okeechobee ASR Pilot Project	Untreated surface water	20 MGD	Proposed

Chapter 4
ANALYTICAL TOOLS

BACKGROUND

No detailed hydrologic model of the Caloosahatchee Basin existed prior to the CWMP. Earlier estimates of demands and runoff in the Caloosahatchee Basin, used in the Restudy, were based on modifications and adjustments to measured flow data to account for basinwide changes in land use. The *Lower East Coast (LEC) Regional Water Supply Plan* process identified the need for a comprehensive hydrologic investigation (analysis) of the Caloosahatchee Basin with a view to quantify demands and runoff from the 582,000 acre basin and its impact to Lake Okeechobee.

As part of the *Caloosahatchee Water Management Plan* (CWMP), two hydrologic models for the Caloosahatchee Basin were developed. Both models are hydrologic models based on basin specific data. The first model was developed based on the Agricultural Field Scale Irrigation Requirements Simulation Model (AFSIRS) in combination with spreadsheet Water Balance (WATBAL) models and represents a relatively simple water budget modeling approach. The model focuses on estimation of irrigation demands and water balance for the basin. Due to its simplicity and computational speed, the AFSIRS/WATBAL modeling approach is well suited for simulation of lengthy periods (such as the 31 year model runs used in the Restudy) and for making statistically meaningful estimates of 1-in-10 drought demands. It is land use based, and can simulate the hydrology of basins that have continuously changing land uses. The models are relatively simple to calibrate and can easily and quickly generate estimates of hydrology for any number of potential land use scenarios. The second model, the Integrated Surface Water/Ground Water Model (ISGM) of the Caloosahatchee Basin and was developed using MIKE SHE. This model is a physically based model and has the capability of examining, surface and ground water interactions as well as specific processes such as transmission losses, local flooding, impact of ground water and or surface water withdrawals, and management of water levels in canals.

In addition to the two hydrologic models, the Optimization model, Opti-5, developed for the SFWMD under contract by John Labadie (1997) was used as a screening tool, for initial component sizing and establishment of operational rules.

Brief Description of the Modeling Area

The portions of the planning area simulated with each of the two models vary slightly to accommodate the strengths and limitations of the models. Generally the area included in the models cover both the East and West Caloosahatchee basins.

The West Caloosahatchee Basin is comprised of two major demand areas, the C-43 demand basin which is supplied from the C-43 Canal, and the ground water demand basin which meets its irrigation needs from ground water sources. The East Caloosahatchee Basin is made up of three demand basins, the C-43 demand basin, the ground water demand basin, and the Lake Okeechobee demand basin. The extents of these basins were established through evaluations of permit data and ground-truthing.

Both models exclude the tidal portions of the CWMP planning area. In addition, the AFSIRS model does not incorporate the S-4 Basin (to the east) and Telegraph Basin (to the west). The AFSIRS model focuses on the estimation of the surface water demands from the C-43 Canal within the East and West Caloosahatchee basin. The MIKE SHE model incorporates both the S-4 and Telegraph basins and focuses on surface water ground water interactions within the basin with an emphasis on surface water flow estimation. The area represented by the AFSIRS model thus represents a subset of the area simulated by the MIKE SHE model. **Figure 13** shows the extent of the model area for the MIKE SHE model.

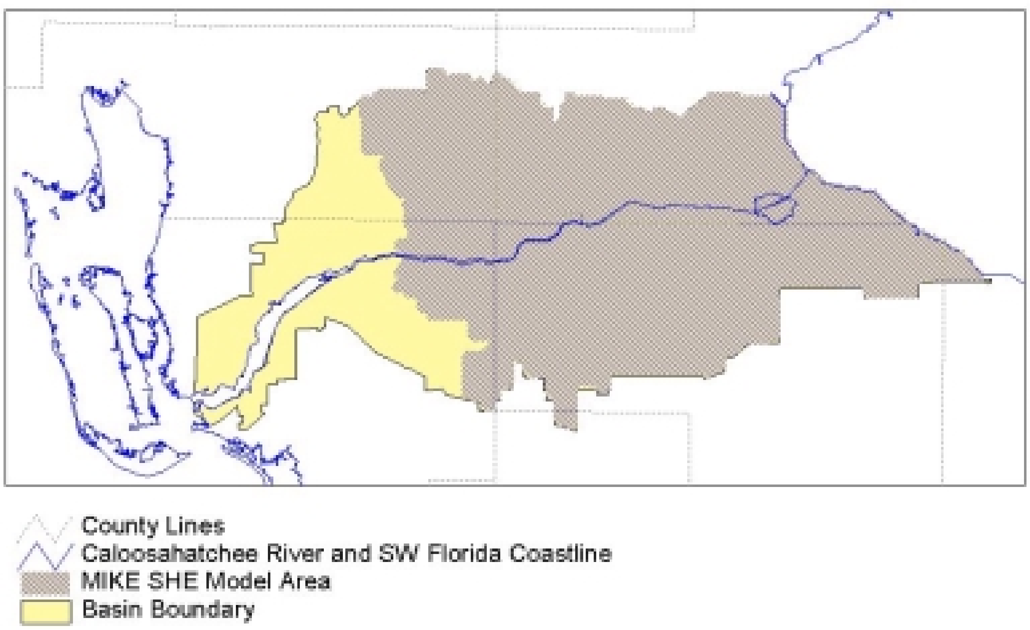


Figure 13. MIKE SHE Modeling Area.

LIMITATIONS OF PREVIOUS DEMAND ESTIMATES

A time-series of Caloosahatchee Basin daily demands and daily runoff was developed in 1997 for use in Restudy modeling. The demand estimates used for 1995 Base simulations of the South Florida Water Management Model (SFWMM) were developed as follows:

- Demands for the period from 1965 through 1971 were based on the predictions of a rainfall-demand model.
- Demands for the period from 1972 through 1980 were based on basin shortfall, computed from measured flow within the basin and adjusted by a factor of 1.4 (the ratio of irrigated acreage in 1990 to the irrigated acreage in the period between 1972 and 1980). A further adjustment by a factor of 1.25 was necessary to account for the change in acreage from 1990 to 1995.
- Demands for the period from 1981 through 1990 were based on basin shortfall, computed from measured flow within the basin and adjusted by a factor of 1.25 (the ratio of irrigated acreage in 1995 to the irrigated acreage in 1990).
- Demands for the period from 1991 through 1995 were based on basin shortfall, computed from measured flow within the basin with no adjustments.

There are two shortcomings in these demand projection methods. At the time these data sets were prepared, land uses within the basin were not well identified. The inability to identify ground water irrigated lands inside of the Lake Okeechobee Service Area (LOSA) resulted in an over count of C-43 irrigated acres (16,894 acres) and caused a 7% underestimation of demands per acre that affects the land use adjustment factor used in predicting 1995 Base demands from historic demand values. The second shortcoming is that this method is not able to model hydrologic processes. As a result, there is no distinction made between low efficiency flood irrigation systems and high efficiency micro drip irrigation systems, and no distinction between sugarcane, vegetables, and citrus. This means that runoff must be considered identical from all land uses. Therefore, runoff does not change as more of the land is converted to urban or irrigated land uses.

A modeling approach that corrects these limitations of the existing methodology was developed and is discussed in the following sections.

WATER BUDGET MODELING

The water budget modeling that was conducted during development of the CWMP is a comprehensive water budget model of the Caloosahatchee Basin based on eight different land uses. Five of the land uses represent major irrigated land types in the basin. Six geographic basins were modeled, each with basin-specific climate data set. Measured long-term flow data exists at two points in the model area. The flow data was used during model calibration process for selection of crop correction coefficients, estimation of local basin storage, estimation of irrigation conveyance losses, determination of root zone storage on nonirrigated lands, and estimation of runoff routing parameters for each land use.

Brief Description of Water Budget Models

The water budget modeling effort utilizes four separate models: AFSIRS, AFSIRS Water Budget, Water Balance Model (WATBAL), and Composite Flows and Statistics. The AFSIRS model is written in Fortran code while the others are spreadsheet models.

The basic premise of the water budget modeling effort is that fields having the same soil, climate, and land use have the same hydrology. It logically follows that every land use is independent of every other land use. It also follows that runoffs or demands from each land use can be added together to produce a composite basin runoff or demand. Although this premise is not strictly true, it allows a land use based analysis of hydrology that would otherwise be impossible.

With this approach, it is more efficient to model the hydrology of each land use using units of volumes per unit area (i.e., inches of water), only converting into volumes (i.e., acre-feet) when determining basin wide runoffs and demands.

AFSIRS

AFSIRS is a computer model that predicts irrigation demands for a particular land use, irrigation method, soil, and climate. The model simulates the hydrology of the root zone and is particularly useful for comparing the application efficiencies of different irrigation methods. AFSIRS uses daily rainfall and reference crop potential evapotranspiration (ETO) to model irrigation demands and root zone excess (sum of runoff and recharge). The model can only be applied to irrigated lands.

The irrigation demands predicted by AFSIRS are termed "field-scale" demands. These demands include application losses but not atmospheric losses.

The only AFSIRS parameters that were varied in this plan were the monthly crop correction coefficients that are used to convert ETO to the potential evapotranspiration of a specific crop (ETi). All other AFSIRS parameters are the standard (default) parameters of a specific irrigation method and crop characteristic.

Soil characteristics were modeled as uniform throughout the basin and were assumed to be equivalent to the "0.8 inch" soil as defined by the SFWMD's *Permit Information Manual*. The "0.8 inch" soil is used in almost all permits within the CWMP region.

AFSIRS was used to simulate the hydrology of four land uses: crown-flood irrigated citrus, micro jet irrigated citrus, subsurface seepage irrigated sugarcane, and a dual crop of spring and winter micro spray irrigated tomatoes. When irrigated pasture is referred to, the runoff and demands are actually those of crown-flood irrigated citrus.

AFSIRS Water Budget

Being a root zone model, AFSIRS does not simulate saturated flow, surface water flow or open-channel flow processes. The AFSIRS Water Budget model postprocesses AFSIRS field-scale runoffs and demands to produce basin-scale demands and runoff. For surface irrigated lands, this model has two parameters for irrigation: atmospheric irrigation efficiency (Eff 1) and local storage depth (Stor l). The model has two parameters affecting the timing of runoff: drainage capacity (Cap l), and a runoff storage coefficient (Coeff 1). All four parameters are optimized during, the calibration process.

- Eff 1: Demands are increased by dividing the field-scale demand by the atmospheric efficiency term. This term increases irrigation demands.
- Stor l: Field-scale demands and runoffs are converted into basin-scale demands and runoff by application of a local storage term. All field-scale demands are removed from local storage until the local storage is depleted. Field-scale runoff must replenish local storage before excess basin-scale runoff can occur. This term decreases both irrigation demands and runoff.
- Cap 1 and coeff 1: A simple linear-reservoir routine model is applied to all runoff. The linear reservoir routine model has two parameters: a drainage capacity parameter that limits maximum runoff and a runoff storage coefficient that describes the rate at which a runoff volume is released. These terms decrease peak runoff rates and delay the entry of runoff into the stream.

When the model is applied to lands irrigated from ground water sources, an additional process is needed to deplete and recharge ground water. For such cases, field-scale runoff recharges the aquifer at a maximum recharge rate defined by the user. It was found that recharge rates greater than 0.4 inches per day have identical results so a rate of 1 inch per day was used in all cases. Because AFSIRS simulates application inefficiencies, the process uses excess irrigation to recharge the ground water aquifer. A second term was added to limit withdrawals from the aquifer and a maximum withdrawal volume of 6 inches was selected for all simulations. This volume was selected because it approximates the informal definition of "no harm" currently used by the SFWMD (e.g., recovery within one year). Because field-scale irrigation demands exceed 20 inches per year, lands that are ground water irrigated frequently cannot meet their own needs. These unmet demands are supplied from runoff from nonirrigated lands in the same demand basin. This occurs in the model "Composite Flows and Stats". The two ground water irrigation parameters affect basin hydrology by reducing runoff from basins that are supplied by ground water.

Finally, a three-day moving mean was used during the process of converting irrigation demands from inches into acre-feet. This approximates a three-day irrigation cycle.

WATBAL

Because AFSIRS can only be used for irrigated lands, a separate hydrologic model is needed for nonirrigated lands. The model WATBAL was written for this. The model is a simple three-parameter "pot" model. It has a root zone "pot" that is replenished by rainfall and depleted by evapotranspiration. As with AFSIRS, monthly crop correction coefficients are used to convert crop potential evapotranspiration (ETO) to the potential evapotranspiration of a specific crop (ETi). When the "pot" is empty, evaporation becomes zero. When the "pot" is overfull runoff occurs. As with the "AFSIRS Water Budget" model, runoff is routed using a linear routine, model.

Only three nonirrigated land uses are simulated in this modeling, effort: wetlands, upland, forest, and pasture. The pasture category contains all miscellaneous land uses.

Composite Flows and Stats

The two AFSIRS models provide estimates of basin-scale runoff and demands for each of five irrigated land uses, while the WATBAL model provides estimates of basin-scale runoff for each of three nonirrigated land uses. These models are applied to each of the five demand basins within the planning area. The result is runoff from eight land uses and demands from each of five land uses for five separate demand basins. The model "Composite Flows and Stats" combines these runoffs and demands and considers interactions between runoff and demands.

The interactions between the hydrology of each land use are limited. Flows from the nonirrigated lands in the two ground water demand basins are used to supply unmet ground water demands. Also, days with simultaneous C-43 demands and runoff within the East Caloosahatchee Basin are resolved so that the day has either demand or runoff. This reduces both runoff and demands, and days with simultaneous C-43 demands and runoff within in the West Caloosahatchee Basin are resolved so that the day has either demand or runoff.

Hydrologic summaries are made in this model and comparative statistics are also calculated in this model.

CWMP Application

The AFSIRS/WATBAL model was used to determine irrigation demands from the C-43 Canal and to generate a time series of demand and runoff from the Caloosahatchee Basin over a 31-year climate regime. The demand and runoff estimates are used to update the Caloosahatchee data in SFWMD regional planning efforts. The demand and runoff estimates, simulated by the AFSIRS/WATBAL model, were verified using MIKE SHE.

INTEGRATED SURFACE WATER/GROUND WATER MODEL

The Caloosahatchee Basin experiences significant interaction between surface water and ground water. A modeling tool capable of representing only the surface water or the ground water components is inadequate to fully represent the hydrology of the basin without significant simplification of the system. An integrated surface water ground water model on the other hand allows the representation of this interaction that is crucial within the Caloosahatchee Basin. The model utilized in the CWMP is the integrated surface water and ground water flows model, MIKE SHE, developed by the Danish Hydraulic Institute (DHI). The MIKE SHE model is a distributed finite difference model, which computes water movement in each cell within the model area. Smaller grid cells result in a more detailed basin description, but has a higher computational cost. As a compromise between detailed model output and computer capacity, a 1,500 ft (457 m) computational grid was applied for the Caloosahatchee Basin model. Parameters and input data are lumped to represent the average conditions within the computational cells. In order to facilitate refinement of the model and development of finer scale subregional models of the Caloosahatchee Basin, input data for the model was prepared at a 500-foot-by-500-foot detail level.

The area encompassed by the model is divided into cells by a model grid (defined by a system of rows and columns). The ground water component of the model generates two principal types of output typical of ground water models, computed head (water levels), which result from the conditions simulated, and water budgets for each active cell. The water budget shows the inflows and outflows for each of the cells. The time scale of the surface water regime and the ground water regime are different. The model allows use of different time steps for calculation of river/canal flow and ground water flow. The river hydraulics model runs in time steps with duration of 15 minutes, while overland flow is solved in 6-hour time steps, and ground water flow calculations are carried out once a day.

The model code applied is modular in nature and consists of a number of components which may be combined to describe flow within the entire land-based part of the hydrological cycle, or tailored to studies focusing on parts of the hydrological system. For the Caloosahatchee Basin, the close link between river/canals and aquifers required that both surface and subsurface components be included. A more detailed description of the MIKE SHE modeling system can be found in Abbott et al. 1986a and 1986b. A summary of the MIKE SHE model for the Caloosahatchee Basin is presented in this section. A detailed report is included in Appendix G to this report.

Ground Water

The model simulates dynamic ground water flow and potential heads. The modeling system utilizes a fully 3-dimensional geological model describing the extent, thickness and elevation of the major geological units, including both aquifers, aquitards, and confining layers. The Surficial and Intermediate aquifer systems are represented in the geological model. The aquifer systems used in the modeling effort include the

Tamiami aquifer, sandstone aquifer, and upper Hawthorn aquifer. These geological layers are assumed to account for the exchange with the river and canal network and to constitute the major source of ground water in the model area. The deeper Floridan Aquifer System (FAS) is not considered to be recharged in the model area or to add to the water available in the above aquifer systems. Regional potential head maps indicate that the primary zone of recharge of the Floridan aquifer is northeast of the model area. This assumption has been made in accordance with previous ground water studies in the area.

Lithological information, in terms of borehole logs, was extracted from previous ground water studies in Lee, Hendry, and Collier counties (Bower et al., 1990). Borehole data from Charlotte and Glades counties is limited so layer thicknesses were extrapolated from Lee and Hendry counties. The Tamiami and the sandstone aquifers cover only the eastern and the western parts of the model area respectively. Irrigation well logs indicate that the two aquifers serve as the primary source of ground water in the basin. The extent of the two aquifers has been assessed partly from the lithological information from boreholes partly from irrigation wells. The water table aquifer and the upper Hawthorn layers are found throughout the model area.

Pump test data are available from 26 locations inside the model area. From the pump test analysis, transmissivities, storage coefficients, and in some wells, leakage coefficients have been derived. The wide range of transmissivity data reflects the varying composition and properties of the screened interval. The density of data is considered insufficient to produce distributed maps of the aquifer properties for each geological layer of the model. The pump test data and previous ground water studies have been used to establish ranges of the parameters. The parameters have been distributed into zones with uniform parameter values.

Ground Water Boundary Conditions

Ground water boundary conditions are specified for all layers in the model. For the upper layer, it is assumed that surface water and ground water divides coincide, subsequently, a no flow boundary has been applied. The surface water divides have been subject to further analysis in order to incorporate man-made changes of drainage paths. The surface water boundary is uncertain in some parts of the basin and flow directions may change depending on local water level changes in response to storms. Consequently, there is also some uncertainty associated with the ground water boundary. The flow, which may occur across the boundary, is most likely insignificant with respect to the water balance.

A no flow boundary has been applied to the lower part of the aquifer system, along with some modification on the southern boundary. The operation of ground water pumps is reported to cause drawdown in this area. They are believed to cause cross boundary ground water flow, which depending on the head gradient, flows into or out of the model area. In order to simulate this condition, time series from 3 observation wells have been applied to generate a dynamic head boundary used in the model for the lower aquifer.

Surface Water

The Caloosahatchee River and its major tributaries, represented by a total of 47 branches, have been included in the river hydraulics model. This river network includes both irrigation and drainage canals. In the western part of the basin, drainage is gravity driven, while drainage flow in the eastern part and pumps control irrigation supply in secondary canals.

The geometry of each channel is input in terms of cross-section data. This is important to both conveyance capacity and storage capacity at different reaches of the conveyance system. Cross-section data is generally scarce for most of the river network included in the model. Therefore, estimated cross-sections were used. Trapezoidal cross-sections have been assumed and canal bank elevation estimated from the topographical data.

The drainage and irrigation network is controlled by a large number of structures. Many of the secondary branches are canals, which have been constructed to provide sufficient conveyance capacity for drainage, sufficient storage capacity for irrigation, or both. To supply surface water to the upstream parts of the basin during dry periods, the water is pumped upstream from the Caloosahatchee River in stages, separated by weirs or gates. Weirs are typically built in connection with pump stations. The pumps are activated when the water level upstream of the weir drops below the minimum acceptable level for irrigation. Water is diverted from the main secondary irrigation canals by pumps or by tertiary ditches and canals. During dry periods the pumps on the primary canals may run continuously to supply water to the upper reaches. Pumping rates are determined by irrigation demands and the availability of water in the Caloosahatchee River.

Major hydraulic structures have been included in the model. Data for 28 weirs and 15 pumps has been incorporated in the river setup. The majority of control structures are located in the southern part of the basin. In addition to the location of each hydraulic structure and the water permits they supply, required data include weir height, weir width, levels for pump operation, pump capacity, and culvert dimensions.

The basin is generally flat with a number of floodplains or depressions (sloughs and swamps) adjacent to the river branches. At high water levels following rainfall events, the river inundates the floodplain. When the river water level recedes, water accumulated on the floodplain drains back to the river. Dynamic floodplain simulation of the river/floodplain interaction is important in order to describe flow attenuation and surface water storage.

Lake Hicpochee and Telegraph Swamp are two major floodplain areas connected to the Caloosahatchee River and Telegraph Creek, respectively. Their storage and conveyance capacity is represented by wide cross-sections incorporating both main canal and floodplain features. The cross-section width increases with increasing water levels and flooding occurs as the water table rises above the bank level.

Overland sheetflow occurs when the water depth on the ground surface is larger than zero. Ponding of water at a specific location is a result of insufficient infiltration capacity of the unsaturated soil column, ground water tables rising above ground, and/or overland flow from neighboring areas. Overland flow only occurs during storm events. More important is the depression storage (i.e., low lying areas receiving overland flow or drainage flow). The surface detention volume is described by the topography. Ponding water accumulates as depression storage until the water level exceeds topographical thresholds separating the depression from surrounding areas. Ponded water may also infiltrate. This is limited either by the infiltration capacity of the underlying unsaturated zone, or when the soil is entirely saturated, the leakage coefficient between the overland component and the saturated zone.

The governing equation for overland flow (2-D Saint-Venant) requires specification of a Manning roughness coefficient, detention storage, and a leakage coefficient. The Manning roughness coefficient describes the ground surface resistance flow within each computational cell and it depends mainly on land use. A uniform value of 10 m1/3/s has been used. Detention storage is a threshold value that describes at which overland water depth flow is initiated. It depends on surface properties, which may vary within a short distance. Distributed average values for each computational cell may be given. Here a uniform value of 0.4 inches (10 mm) has been applied. Exchange of flow between overland and the ground water may take place when the soil is completely saturated. The leakage coefficient is used to describe the hydraulic contact between ground water and overland flow. Overland water depth and flow velocities are calculated in maximum time steps of 6 hours. The time step is reduced at high rainfall intensity.

Unsaturated Zone

The unsaturated zone extends from the ground surface to the ground water table. The depth of the unsaturated soil column is dynamic and varies throughout the simulation period. It increases with decreasing ground water table and decreases when the ground water table rises. The unsaturated zone may vanish when the ground water table rises above the ground surface and saturated conditions prevail.

Due to the dynamics of the ground water table, the unsaturated zone properties must be specified from the ground surface down to the lowest ground water level occurring during the simulation period. Hydraulic properties of both the saturated zone and the unsaturated zone must be specified in an overlapping region covering the range of ground water table fluctuations.

Unsaturated zone flow is important to simulate infiltration, vertical flow through the soil column, and recharge to the ground water. Simulation of the vertical soil water profile requires a detailed description of the actual soil properties. The soil water content is of particular importance with respect to calculation of evapotranspiration losses from the root zone and irrigation demands.

Characteristic Soils

Most of the soils of Southwest Florida are shallow and sandy with high water tables. They are characterized by high to very high permeability, high porosity, and little or no capillary rise. The texture and hydraulic properties of the soils varies both on local and regional scale. To provide a horizontal and vertical distribution of soil physical parameters, characteristic soil types have been identified from landscape classifications. Soils coverage was obtained for all six counties (Charlotte, Collier, Glades, Hendry, Lee, and Palm Beach), within the Caloosahatchee Basin. There are approximately 70 different soil-mapping units in the basin. Many of these mapping units have similar physical characteristics and are assumed to behave in a hydrologically similar manner.

For the purpose of this simulation, soils were classified in different hydrologic response groups. These hydrologic response groups are flatwoods, marshes and ponds, sloughs, depressions, rock (shallow soils on limestone), and 'unsuitable'. The hydrologic response groups are based on the range productivity landscape classes. Six different landscape types have been identified and related to characteristic soil types. Each landscape type is distributed and associated with a standard soil profile including the soil horizons found from field surveys. Each soil type in the profile is represented by thickness and the soil physical parameters.

As a result of the high infiltration rates and moderate to high horizontal conductivity of the water table aquifer, significant overland flow occurs only during extreme rainfall events. The overland flow direction and velocity is determined by the ground surface slope. The input surface topography map is based on 5-foot elevation contour maps supplemented by discrete spot elevations. Flows and water levels are simulated within all major drainage and irrigation canals in the basin. The river hydraulics model is dynamically coupled to the ground water model. The vertical flow in the unsaturated soil column and the water content profile is calculated solving the equation for gravity flow. The unsaturated zone does not require specification of boundary conditions. The ground water table of the upper aquifer constitutes the lower boundary for the unsaturated zone within each of the soil columns. The upper boundary may act as a flux boundary when the soil has sufficient infiltration capacity. When the infiltration capacity is exceeded a head boundary is applied depending on overland water depth. When ground water tables rise above the ground surface the unsaturated zone flow calculations are replaced by the ground water component. The vertical flow in the unsaturated zone is calculated in each time step for all of the 12,997 computational columns.

Rainfall

The rainfall distribution is highly variable in both time and space. Local thunderstorms account for considerable rainfall volumes. Accumulated rainfall from the stations in the basin and the surrounding areas do not show a clear geographical pattern and the total rainfall at the stations is generally determined by local weather phenomena. Rainfall data from 9 stations were selected to represent the rainfall input in the model area. The measured time series were gap-filled by transferring values from neighboring stations. The rainfall input for the model was spatially distributed according to Thiessen polygons. The average rainfall for S-79 is 51 inches/year for the period 1980-1995 and slightly lower (48 inches/year) for the eastern part of the basin (S-78). The driest year was 1981 (36 inches/year) and the wettest 1995 (66 inches/year). The highest rainfall is seen in the period June-August and the lowest in December-April.

Evapotranspiration (ET) accounts for the bulk of water losses from the Caloosahatchee Basin. The water is lost to the atmosphere reducing the water available for surface and subsurface runoff. Land use data are primarily used for distributing vegetation characteristics applied for simulation of actual evapotranspiration in the model. The ET module simulates interception and evaporation from vegetation cover, soil and free water surface evaporation, and plant transpiration from the root zone.

The Leaf Area Index (LAI) is calculated as the total leaf area of the vegetation per unit ground surface area. This index is a measure of the vegetation surface area available for transpiration, and may be time varying for seasonal vegetation while perennial vegetation may be considered constant. Harvested crops such as sugar cane and truck crops are described by vegetative stages covering the growth period. Root Mass Distribution (RDF) is the percentage of active root mass in a specific depth of the root zone. A rooting depth is specified (extinction depth) and the root mass is distributed vertically by an exponential function. The RDF and the vertical soil moisture profile of the root zone affect the actual ET rate in each depth interval of the root zone and as total integrated for the entire root zone.

The LAI and RDF are vegetation specific parameters. The distribution of vegetation parameters is based on the identification of the dominant characteristic vegetation/land use types in the basin. Land use maps were applied to distribute vegetation specific parameters. The land use in the basin has been classified into land use and land cover classification codes.

The model simulates the actual ET rate. It is calculated at each time step as a percentage of the potential evapotranspiration (PET) rate. Measured time series of PET rates must thus be specified as part of the model input. Two sets of PET data exist for the Caloosahatchee Basin: measured pan evaporation data and Penman estimates based on meteorological data (solar radiation, temperature, humidity, and wind speeds).

The data are primarily used to simulate soil or free water surface evaporation and plant transpiration. Consequently, a crop vegetation specific potential evapotranspiration rate is needed for input to the model. The Penman data are considered the best-suited data, and time series from three stations have been applied (LaBelle, Fort Myers, and Moore Haven).

Irrigation Demand

Little data exist to shed light on irrigation practices (i.e., when farmers start irrigating and the actual supply rates and volumes). Field surveys in the Caloosahatchee

Basin do not provide any operational rules that could be assumed valid for the basin in general. The irrigation demand depends on many factors and is highly variable in time. Calculation of irrigation demands relies on estimates of actual evapotranspiration. This approach is based on available meteorological data and aims at calculating the supplemental water required to maintain potential rates of evapotranspiration for the respective crops.

A general assumption has been adopted for the water allocation. First and second priority is given to nearby irrigation canals while third priority is given to shallow ground water wells. Exceptions have been made in areas with no irrigation canals and a large density of irrigation ground water wells and in the eastern part of the basin where water is pumped directly from Lake Okeechobee. The canal flow and storage may not be sufficient to meet irrigation demand, in which case, for most areas, it would allocate water from the aquifer.

The efficiency of the irrigation scheme is always less than 1.0, implying that water is lost from the source to the point of application. In addition, the water distributed in the field may not be available for crop transpiration due to a number of factors. If the supply rate exceeds the infiltration capacity of the soil water is lost due to overland flow or free surface evaporation, if the soil is already saturated or if water percolates below the root zone. If the soil becomes saturated when the ground water table rises there is no soil water deficit in the root zone and subsequently demand and supply equals zero. Due to the relatively high conductivities of the soils in the Caloosahatchee Basin and the frequent supply of irrigation water, the infiltration capacity is rarely exceeded. In each time step the irrigation water demand is approximately equal to the water lost from the root zone from evapotranspiration. On irrigated areas the percolation to the surficial aquifer is thus limited.

Canal conveyance losses are accounted for as canal-aquifer exchange along the river branches included in the MIKE 11 model (all primary canals) until the irrigation outtake points. Seepage from the canal system may occur if the head gradient is positive from the canal towards the aquifer. That does not change the demand but in response to significant conveyance losses a higher pumping rate from the Caloosahatchee is required to maintain water levels in the irrigation canal. The water seeping into the aquifers will eventually reappear as a baseflow contribution in the downstream part of the canal system.

MIKE SHE Model Calibration and Validation

The objective of the model development is to provide a modeling tool capable of assessing the impact of the extensive conjunctive use of ground water and surface water on the total water balance. To be used for predicting effects of future management initiatives the model must be able to simulate historical records in the basin.

The canals are the primary source of irrigation water and in the calibration process first priority was given to simulating the dry period canal flow. The second priority was to obtain the approximate storm peak discharges and total accumulated runoff. The lateral contributions to river flow are overland flow, seepage between aquifer-canals, and drainage flow.

The storm discharge is dominated by overland and drainage flow contributions. Calibration of surface water has focused on the drainage response. The drainage depth and drainage time constant of areas considered drained has been subject to changes. The drainage depth has been varied between 1.6-4.1 feet (0.5-1.25 m). Increasing the drainage depth will effectively increase the volume of ground water discharged into the canals and thus the downstream peak flows.

The simulated low flow is a function of surface water diversion at S-77, storage in the canals, the aquifer baseflow and the irrigation water outtake from the canals. Applying small leakage coefficients reduce the aquifer baseflow and adjusting drainage levels to minimize dry period drainage flow. Parameters affecting calculated irrigation demand were tested by changing the root depth 1.6-4.9 ft. (0.5-1.5 m). The rooting depth was not found to change the total demand significantly in irrigated areas. The LAI (1.0-6.0) is generally not limiting the actual evapotranspiration.

To test whether the selected set of model parameters applies to both dry and wet conditions the model is calibrated for a period with both dry and wet years (1986-1990). Field measurements constitute the primary calibration references. In the Caloosahatchee model, river/canal discharges and ground water levels are used to calibrate the model. The time series of observed potential heads have been collected as part of previous ground water flow studies for Lee, Hendry, and Glades counties. They have been assigned to the deep and shallow aquifers respectively (water table aquifer and sandstone aquifer) from well screen information. All of the available observation wells are located in the southern part of the model area. Twelve shallow wells and twelve deep wells are found inside the model area south of the Caloosahatchee River.

Key calibration parameters for the model simulation are Manning roughness coefficient numbers and leakage coefficients for the exchange of water with the aquifer. The Manning roughness coefficient numbers applied in the model range from 20 to 50 m1/3/s. From comparison of discharge time series at S-77, S-78, and S-79 it is seen that the delay in time and the reduction in peak flows in the Caloosahatchee is very limited. Consequently, high Manning coefficient numbers have been applied in this part of the system. Both primary and secondary canals are generally kept free of vegetation. The bed leakage coefficients are specified for each branch of the river system and describe the hydraulic contact between the river and the aquifer. The exchange of flow is described by a Darcy approximation as a function of the head gradient and the leakage coefficient. The hydraulic contact is relatively high except for parts of the system where organic matter and sedimentation reduces the conductivity along the canal bed lining. A uniform value of 1e-6 s-1 has been applied for the entire river network. The leakage coefficient is likely to vary but the available data has not supported a distributed description.

The computational time step applied is 10 minutes. The time step has been chosen from the time scales and numerical constraints.

The period 1994-1998 was chosen for model validation. The same parameters applied in the calibration were used in the validation. Significant changes in land use and an increase in irrigated area must, however, be incorporated to properly represent the field conditions. The validation of the model can be used to investigate if the model parameters applied in the calibration period may be considered valid for the entire period 1986-1998 and if the model is capable of simulating the ongoing land use change in the basin. The irrigation canal network and ground water wells locations are assumed identical for the two calibration periods implying that the irrigation canal system, but not necessarily the irrigation water demand, is unchanged. To minimize the uncertainty of model simulations in relation to impact analysis it is recommended that model results be interpreted in terms of changes relative to a base scenario.

MIKE SHE Summary

A fully dynamic and integrated hydrological model was developed incorporating all major flow processes in the Caloosahatchee Basin. The model was based on available data on meteorology, soil physics, hydrogeology, canal geometry (including hydraulic control structures), land use, crop, and irrigation data. The modeling system is comprehensive and so are the input data requirements. Where data have been insufficient, estimates or generalized assumptions were made to complete the model. The validity of the assumptions and the sensitivity of the model to selected model parameters were investigated. It was found that the effective ground water drainage depths in agricultural areas were important to the model results and associated with some uncertainty.

Through the calibration and verification process, it was demonstrated that the modeling system is able to simulate dynamic surface and ground water flows, including the irrigation water stress. The model was used to provide an impact assessment of various water resources management alternatives including both surface and subsurface water resources. In addition, the model was used in evaluating environmental effects to the estuary and wetlands by utilizing alternative simulations.

The irrigation water demand and corresponding conjunctive allocation of ground water/surface water is based on the fully distributed and fully dynamic simulation of the actual soil water content and actual rate of evapotranspiration. The approach takes into account crop and soil characteristics.

CWMP Application

The MIKE SHE model was used for detailed scenario analyses in the CWMP. The model was also used to verify the basin demand and runoff for a 31-year climate regime based on the projected 2020 land use data. Details of the methodology and the results of the alternative analyses are presented in Chapter 6 of the Planning Document.

Chapter 5
RESOURCE REGULATION

BACKGROUND

Resource regulation is implemented through a number of agencies, with the District's work being the most pervasive. Local governments have the greatest impact in the urban and suburban areas of the basin. Federal permits are required for selective issues, and in many cases, the District coordinates with other state agencies is areas in which they are the lead authority. The general federal and state authorities have been described in other district planning activities, and are summarized and contained in Chapter 1 and Chapter 3.

It should be noted that the Caloosahatchee River is part of the "Save the Everglades" initiative, and the headwaters of the Caloosahatchee and its receiving estuarine basin are part of the Charlotte Harbor National Estuary Program (CHNEP). The CHNEP will be completing its management plan in 2000. The District, as well as Lee and Charlotte counties, and the cities of Fort Myers and Cape Coral are members of the CHNEP policy board.

The District implements two permitting programs for wetland protection and water resource allocation: the Environmental Resource Permitting (ERP) Program and the Water Use Permitting (WUP) Program. Both require an evaluation of wetland impacts which may occur due to an applicant's request.

DISTRICT ENVIRONMENTAL RESOURCE PERMITTING

The ERP Program deals with the construction of surface water management systems and dredge and fill activities. Surface water management systems are required for all forms of development ranging from agriculture to commercial and residential. This means that developed sites containing more impervious surfaces or altered topography, must provide a way for storm water to be directed to water management areas for water quality treatment and flood attenuation.

During the ERP process, wetlands are evaluated both on and adjacent to the project site. If wetland impacts are proposed in an ERP application, an analysis is conducted to determine if the impacts can be eliminated or reduced (Basis of Review, Vol. IV). Impacts to wetlands can occur through direct physical alteration, such as filling or dredging, or through alteration of the normal hydrologic regimes, such as lowering of the water table. All types of impacts are reviewed during the ERP process.

If the proposed wetland impacts are determined to be permittable, an applicant will need to provide compensation for the loss of the wetland functions. Generally this is accomplished through mitigation, consisting of the restoration or enhancement of existing wetlands, the creation of new wetland habitat, or a combination of these methods. The mitigation areas must be monitored and maintained over the long-term and protected with a conservation easement.

If the applicant proposes to preserve the wetlands on the project site, an analysis is conducted to determine what effects the development will have on the wetlands. An applicant must provide an upland buffer, must ensure that adequate quantities of water will be available to wetlands and that the wetlands will not be over inundated for prolonged periods of time. A conservation easement is required to ensure the long-term protection of the wetlands.

DISTRICT WATER USE PERMITTING

All water uses within the District require permit authorization from the District. An exception from the permit requirement is water used in a single family dwelling or duplex, provided that the water is obtained from one well for each single family dwelling or duplex, and is used either for domestic purposes or outdoor uses. Water used for fire fighting and the use of reclaimed water is also exempt from permitting. A water use permit will be granted as long as the applicant demonstrates that the proposed water use is consistent with the public interest, is a reasonable-beneficial use of water, and one that will not interfere with any existing legal use of water.

The District issues permits for water withdrawals via the Water Use Permitting (WUP) Program. The *Management of Water Use Permitting Information Manual Volume III* (1993), commonly referred to as the Water Use Basis of Review or BOR, is the document that identifies the procedures and information used by District staff in permit application review. The permitting process involves reviewing water use permit applications for consistency with criteria in the District's Basis of Review (BOR). Chapter 2 of the BOR, Water Need and Demand Methodologies, includes criteria for demonstration of need, calculation of water demands, and water conservation requirements for the different use classes. The criteria in Chapter 3, Water Resource Evaluations, address the evaluation of the potential impacts to the resource, existing legal users, the environment, saline water intrusion, and water quality degradation.

The District issues water use permits in two forms, individual water use permits and general water use permits. An individual water use permit is issued for projects whose average day water use exceeds 100,000 gallons per day (GPD) while general permits are issued when the use does not exceed 100,000 GPD, except in areas designated as Reduced Threshold Areas (RTAs). The duration of a general permit is 20 years, while an individual permit is based on the applicant's demonstrated ability to meet demand. This generally does not exceed ten years for public water supply and industrial uses, and three years for dewatering. Duration for irrigation permits (except for golf) is normally established by basin expiration dates, which in the Caloosahatchee Basin is December 15, 2001 (this date may change as part of rulemaking). Golf uses are not to exceed the lesser of the basin expiration date or three years. The District has issued individual consumptive use permits in the basin.

Table 5. Individual Permit Allocations.

Water Use Category	Number of Permits	Daily Allocation (MGD)	Annual Allocation (MGY)	Percent of Total Allocations
Agriculture[a]	673	1358.9	496,000	50
Public Water Supply	44	154.8	56,491	6
Industrial	48	712.7	260,124	26
Recreation[b]	372	75.5	27,565	3
Mining and Dewatering	29	186.1	67,916	7
Other	5	238.8	87,164	9
Total	1,171	2726.7	995,260	100

a. Includes agriculture, aquaculture, livestock, and nursery.
b. Includes golf courses and landscape.
Source: SFWMD 1999, Consumptive Use Permitting Program data.

Areas with Increased Permitting Restrictions

An increased level of water use permitting restrictions is applied to areas where there is potentially a lack of water available to meet demands. These areas include Reduced Threshold Areas (RTAs), Areas of Special Concern, Water Resource Caution Areas and Restricted Allocation Areas (RAAs).

Reduced Threshold Areas

The volume of usage that delineates a general permit from an individual permit is referred to as the permit threshold. In most of the District, the permit threshold is 100,000 GPD. The District has reduced this threshold to 10,000 GPD average or 20,000 GPD maximum in resource depleted areas, where there has been an established history of substandard water quality, saline water movement into ground water and surface water bodies or should water be unavailable to meet projected needs of a region. These areas are referred to as RTAs. Two RTAs exist in the Caloosahatchee Basin: Lee County, and the Muse/LaBelle area of Glades and Hendry counties. Under the District's rulemaking effort, it is proposed to eliminate the RTA category.

Areas of Special Concern

Areas of Special Concern are areas where there are limitations on water availability or there are other potentially adverse impacts associated with a proposed withdrawal. These areas are determined by the District on a case-by-case basis. There are no designated areas of special concern in the Caloosahatchee Basin.

Water Resource Caution Areas

Water Resource Caution Areas are areas that have existing water resource problems or areas in which water resource problems are projected to develop during the next 20 years. These areas were formerly referred to as critical water supply problem areas and were required to be designated by rule by each water management district pursuant to Chapter 62-40, F.A.C. This chapter further states that applicants in these areas must make use of a reclaimed water source unless the applicant demonstrates that its use is not economically, environmentally or technologically feasible. All of the Caloosahatchee Basin is designated as a water resource caution area. The Water Resource Implementation Rule requires these designations be updated within one year of completion of the *District Water Management Plan* and its future updates.

Restricted Allocations Areas

Areas designated within the District for which allocation restrictions are applied with regard to the use of specific sources of water are known as Restricted Allocation Areas (RAAs). The water resources in these areas are managed in response to specific sources of water for which there is a lack of water availability to meet the needs of the region from that specific source of water. There are no RAAs within the basin; however, this designation exists in the other three planning areas.

WATER SHORTAGE MANAGEMENT

Water shortages, and the associated restrictions, are declared by the District's Governing Board when there is not enough water available for present or anticipated needs, or when a reduction in demand is needed to protect water resources. Ground water and surface water levels are continuously monitored, and if they fall to levels considered critical for the time of year and anticipated demands, then the water shortage process is initiated. There are different levels of drought, and these require corresponding levels of restrictions. Water shortage declarations range from a warning, which has voluntary moderate restrictions, through four phases of water shortage, to an emergency, which can restrict withdrawals up to the point of disallowing any further withdrawals from a source.

The water shortage phases reflect the percent reduction in withdrawals necessary to reduce demand to the anticipated available water supply (**Table 6**).

The phases are as follows:

Phase I: Moderate - up to 15 percent reduction

Phase II: Severe - up to 30 percent reduction

Phase III: Extreme - up to 45 percent reduction

Phase IV: Critical - up to 60 percent reduction

Table 6. History of Water Shortages.

Year	Order #	Restrictions	Area Affected
1988	88-03 88-07	Phase I Moderate Restriction; Rescinded 88-03	Coastal Lee County (excluding the offshore islands south to Coconut Road)
1989	89-03 92-01	Phase I Moderate Restriction; ground water	Portions of Lee County, Glades County, Hendry County, and Collier County All areas
1989	89-14 92-01	Phase I Moderate Restriction; ground and surface water	Hendry County All areas
1990	90-01	Phase III Agriculture	EAA/Lake Shore Perimeter
1990	90-02	Phase I Moderate Restriction; Nonagriculture	EAA/Lake Shore Perimeter (see also 90-10 & 90-27)
1990	90-04	Phase I Moderate Restriction; surface water	Portions of Hendry County Caloosahatchee Basin
1990	90-05	Phase I Moderate Restriction; ground water	Portions of Collier County (Bonita Springs); Caloosahatchee River Basin
1990	90-06	Phase II Severe Restriction; surface water	Portions of Hendry County Caloosahatchee River
1990	90-07 90-27	Phase I Moderate Restriction; ground and surface water Modified Phase I	Bonita Springs/North Naples; Portions of Lee and Collier County; Caloosahatchee River Basin- South Water Use Basin
1990	90-08	Phase I Moderate Restriction; ground water	Western Lee County; Caloosahatchee River Water Use Basin, including Basin North and Basin South Water Use Basins
1990	90-10	Modified previous orders to exclude the recirculating fountains	
1990	90-13	Phase II Severe Restriction; agricultural uses of ground water	Portions of Glades and Hendry Counties in the Caloosahatchee River Basin North Water Use Basin
1990	90-14	Phase II Severe Restriction; ground and surface water	Portions of Lee and Collier Counties including Coastal Collier County Water Use Basin and Caloosahatchee River Basin - South Water Use Basin; Bonita Springs/North Naples
1990	90-15 90-27	Phase I Moderate Restriction; ground and surface water Modified Phase I	Coastal Collier County; Caloosahatchee River Basin- North and South Water Use Basin
1990	90-23	Phase II Severe Restriction; ground and surface water	Lee County in the Caloosahatchee Basin and its Basin North and South Water Use
1990	90-24 90-27	Phase I Moderate Restriction; ground and surface water Modified Phase I	Portions of West Lee County in the Caloosahatchee Basin and its basin North and South Water Use
1990	90-27 92-01		Modified 90-15, 90-24 and 90-07 to a Modified Phase I
1990	90-28	Rescinded 90-16 and 90-25	
1990	90-29 92-01		Modified WS Order 90-27 to change Golf Course Irrigation schedule Sept. 13, 1990.
1991	91-01 92-01	Phase I Moderate Restriction; ground and surface water	Coastal Collier County Water Use Basin and Caloosahatchee River Basin South Water Use Basin (Bonita Springs/North Naples)
1991	91-04 92-01	Specific Restrictions	Order rescinding 92-01 and Declaring Modified Phase I Restriction within the coastal Collier County Water Use Basin and the Caloosahatchee River Basin South Water Use Basin (92-01 rescinded 25 water shortage orders)

Table 6. History of Water Shortages.

Year	Order #	Restrictions	Area Affected
1992	92-03 93-45	Phase I Moderate Restriction; ground water and surface water Warning	Coastal Collier County (Bonita Springs and North Naples) and Caloosahatchee River Basin South Water Use Basin Declaration of Water Shortage Warning within the coastal Collier County Water Use Basin, the Fakahatchee South Water Use Basin, the Fakahatchee North Water Use Basin, the Caloosahatchee River Water Use Basin, the Caloosahatchee River Basin-North Water Use Basin, the Caloosahatchee River Basin-South Water use Basin
1997	97-30	Phase I Surficial Aquifer System	

Each declared source class is assigned a water shortage phase, and source classes can be combined if appropriate. A water shortage warning has the same restrictions associated with a Phase I, but participation is voluntary. Any of the phases of water shortage can be modified by the Governing Board if necessary. The District's Water Shortage Plan is located in Chapter 40E-21, F.A.C. The current water shortage procedure was originally adopted by the District in 1982. Prior to that, restrictions were made during periods of drought but did not necessarily correspond to the current requirements of the phases of water shortage. Few changes to the District's Water Shortage Plan have been made since that time. The District proposes to review the existing restrictions to determine whether these restrictions need updating, during the rulemaking process.

LOCAL GOVERNMENTS – COMPREHENSIVE PLANS

The touchstone of local government planning and regulations is its comprehensive planning documents. Upon the basis of the comprhensive plan, the local government has the general law authority to undertake local land development regulation. This bundle of authority is referred to as "Growth Management" and is contained in Part II "County and Municipal Planning" of Chapter 163, Florida Statutes.

As a general statement, the local plans for Charlotte, Glades, Hendry, and Lee counties, and the municipalities of Cape Coral, Clewiston, Fort Myers, LaBelle, and Moore Haven, contain the policy framework necessary for environmental resource regulation. All local plans, though, defer to state and federal regulatory agencies for the technical expertise for environmental permitting. Lee County does have a separate staff for review of development proposals for environmental impact, and the county does undertake technical assessments for proposals affecting the county water supply, sewerage disposal, and storm water operations. The cities of Cape Coral and Fort Myers have similar operations; Charlotte County has a similar capacity, but the portion of its jurisdiction within the basin does not have development activity. A more detailed discussion of the Comprehensive Plan for each juridiction of the basin is contained in Chapter 2 of the Support Document.

WELLHEAD PROTECTION ORDINANCES

The purpose of a wellhead protection program is to protect the ground water in the vicinity of a public water supply wellfield from potential sources of contamination. A wellhead protection program entails a management process that acknowledges the relationship between activities that take place in wellfield areas and the quality of the ground water supply for those wells. A Wellhead Protection Area (WHPA) is delineated as the surface area, projected from the subsurface, surrounding a well or wellfield through which water (and potential contaminants) will pass and eventually reach the well(s).

The boundaries (zones) of the WHPAs are determined based on a variety of criteria (e.g., travel time, drawdown, distance, etc.) and methods (e.g., analytical/ numerical flow models, fixed radii, etc.). Factors such as the aquifer physical characteristics, aquifer boundaries, the extent of pumping, the degree of confinement, the vulnerability of the aquifer to surface contamination, and the degree of development and land use activity surrounding the well(s) are used in the process. Because methods/criteria employed and physical conditions vary, WHPAs can range anywhere from a distance of a few hundred feet to several miles from pumping wells. Management activities commonly employed within these protection areas include regulation of land use through special ordinances and permits, prohibition of specified activities, and acquisition of land.

GLOSSARY

Acre-foot The volume would cover one acre to a depth of one foot; 43,560 cubic feet; 1,233.5 cubic meters; 325,872 gallons.

Application Efficiency The ratio of the volume of irrigation water available for crop use to the volume delivered from the irrigation system. This ratio is always less than 1.0 because of the losses due to evaporation, wind drift, deep percolation, lateral seepage (interflow), and runoff that may occur during irrigation.

Aquifer A portion of a geologic formation or formations that yield water in sufficient quantities to be a supply source.

Aquifer Compaction The reduction in bulk volume or thickness of a body of fine-grained sediments contained within a confined aquifer or aquifer system. The compaction of these fine-grained sediments results in subsidence, and sometimes fissuring, of the land surface.

Aquifer Storage and Recovery (ASR) The injection of freshwater into a confined aquifer during times when supply exceeds demand (wet season), and recovering it during times when there is a supply deficit (dry season).

Aquifer System A heterogeneous body of intercalated permeable and less permeable material that acts as a water-yielding hydraulic unit of regional extent.

Artesian When ground water is confined under pressure greater than atmospheric pressure by overlying relatively impermeable strata.

Available Supply The maximum amount of reliable water supply including surface water, ground water and purchases under secure contracts.

Average-day Demand A water system's average daily use based on total annual water production (total annual gallons or cubic feet divided by 365).

Average Irrigation Requirement Irrigation requirement under average rainfall as calculated by the District's modified Blaney-Criddle model.

Backpumping The practice of pumping water that is leaving the area back into a surface water body.

Basin (Ground Water) A hydrologic unit containing one large aquifer or several connecting and interconnecting aquifers.

Basin (Surface Water) A tract of land drained by a surface water body or its tributaries.

BEBR Bureau of Economic and Business Research is a division of the University of Florida, with programs in population, forecasting, policy research and survey.

Best Management Practices (BMPs) Agricultural management activities designed to achieve an important goal, such as reducing farm runoff, or optimizing water use.

BOR Basis of Review (for Water Use Applications with the South Florida Water Management District).

Brackish Water with a chloride level greater than 250 mg/L and less than 19,000 mg/L.

Budget (water use) An accounting of total water use or projected water use for a given location or activity.

Central and Southern Florida Project Comprehensive Review Study (Restudy) A five-year study effort that looked at modifying the current C&SF Project to restore the greater Everglades and South Florida ecosystem while providing for the other water-related needs of the region. The study concluded with the Comprehensive Plan being presented to the Congress on July 1, 1999. The recommendations made within the Restudy, that is, structural and operational modifications to the C&SF Project, are being further refined and will be implemented in the Comprehensive Everglades Restoration Plan (CERP).

Cone of Influence The area around a producing well which will be affected by its operation.

Control Structures A man-made structure designed to regulate the level and/or flow of water in a canal (e.g., weirs, dams).

Conservation (water) Any beneficial reduction in water losses, wastes, or use.

Conservation Rate Structure A water rate structure that is designed to conserve water. Examples of conservation rate structures include but are not limited to, increasing block rates, seasonal rates and quantity-based surcharges.

Consumptive Use Use that reduces an amount of water in the source from which it is withdrawn.

Cryptobiosis The ability of an organism to enter an inactive or quiescent state.

Demand The quantity of water needed to be withdrawn to fulfill a requirement.

Demand Management (Water Conservation) Reducing the demand for water through activities that alter water use practices, improve efficiency in water use, reduce losses of water, reduce waste of water, alter land management practices and/or alter land uses.

Demographic Relating to population or socioeconomic conditions.

Desalination A process which treats saline water to remove chlorides and dissolved solids.

Domestic Use Use of water for the individual personal household purposes of drinking, bathing, cooking, or sanitation.

Drawdown The distance the water level is lowered, due to a withdraw at a given point.

DWMP District Water Management Plan. Regional water resource plan developed by the District under Section 373.036, F. S.

Effective Rainfall The portion of rainfall that infiltrates the soil and is stored for plant use in the crop root zone, as calculated by the modified Blaney-Criddle model.

Evapotranspiration Water losses from the surface of soils (evaporation) and plants (transpiration).

Exotic Nuisance Plant Species A non-native species which tends to out-compete native species and become quickly established, especially in areas of disturbance or where the normal hydroperiod has been altered.

FASS Florida Agricultural and Statistics Service, a division of the Florida Department of Agriculture and Consumer Services.

Flatwoods (Pine) Natural communities that occur on level land and are characterized by a dominant overstory of slash pine. Depending upon soil drainage characteristics and position in the landscape, pine flatwoods habitats can exhibit xeric to moderately wet conditions.

Florida Water Plan State-level water resource plan developed by the FDEP under Section 373.036, F.S.

Governing Board Governing Board of the South Florida Water Management District.

Ground Water Water beneath the surface of the ground, whether or not flowing through known and definite channels.

Harm *(Term will be further defined during proposed Rule Development process)* An adverse impact to water resources or the environment that is generally temporary and short-lived, especially when the recovery from the adverse impact is possible within a period of time of several months to several years, or less.

Hydroperiod The frequency and duration of inundation or saturation of an ecosystem. In the context of characterizing wetlands, the term hydroperiod describes that length of time during the year that the substrate is either saturated or covered with water.

IFAS The Institute of Food and Agricultural Sciences, that is the agricultural branch of the University of Florida, performing research, education, and extension.

Infiltration The movement of water through the soil surface into the soil under the forces of gravity and capillarity.

Inorganic Relating to or composed of chemical compounds other than plant or animal origin.

Irrigation The application of water to crops, and other plants by artificial means.

Irrigation Audit A procedure in which an irrigation systems application rate and uniformity are measured.

Irrigation Efficiency The average percent of total water pumped or delivered for use that is delivered to the root zone. of a plant.

Irrigation Uniformity A measure of the spatial variability of applied or infiltrated water over the field.

Lake Okeechobee Largest freshwater lake in Florida. Located in Central Florida, the lake measures 730 square miles and is the second largest freshwater lake wholly within the United States.

Leakance Movement of water between aquifers or aquifer systems.

Leak Detection Systematic method to survey the distribution system and pinpoint the exact locations of hidden underground leaks.

Levee An embankment to prevent flooding, or a continuous dike or ridge for confining the irrigation areas of land to be flooded.

Level of Certainty Probability that the demands for reasonable-beneficial uses of water will be fully met for a specified period of time (generally taken to be one year) and for a specified condition of water availability, (generally taken to be a drought event of a specified return frequency). For the purpose of preparing regional water supply plans, the goal associated with identifying the water supply demands of existing and future reasonable beneficial uses is based upon meeting those demands for a drought event with a 1-in-10 year return frequency.

Marsh A frequently or continually inundated wetland characterized by emergent herbaceous vegetation adapted to saturated soil conditions.

Micro Irrigation The application of water directly to, or very near to the soil surface in drops, small streams, or sprays.

Mobile Irrigation Laboratory A vehicle furnished with irrigation evaluation equipment which is used to carry out on-site evaluations of irrigation systems and to provide recommendations on improving irrigation efficiency.

NGVD National Geodetic Vertical Datum, a nationally established references for elevation data relative to sea level.

NRCS The Natural Resources Conservation Service is a federal agency that provides technical assistance for soil and water conservation, natural resource surveys, and community resource protection

One-in-Ten Year Drought Event A drought of such intensity, that it is expected to have a return frequency of 10 years (see Level of Certainty).

Organics Being composed of or containing matter of, plant and animal origin.

Overhead Sprinkler Irrigation A pressurized system, where water is applied through a variety of outlet sprinkler heads or nozzles. Pressure is used to spread water droplets above the crop canopy to simulate rainfall.

Per Capita Use Total use divided by the total population served.

Permeability Defines the ability of a rock or sediment to transmit fluid.

Potable Water Water that is safe for human consumption (USEPA, 1992).

Potentiometric Head The level to which water will rise when a well is drilled into a confined aquifer.

Potentiometric Surface An imaginary surface representing the total head of ground water.

Process Water Water used for nonpotable industrial usage, e.g., mixing cement.

Projection Period The period over which projections are made. In the case of this document, the 25 year period from 1995 to 2020.

Public Water Supply (PWS) Utilities Utilities that provide potable water for public use.

Rapid-Rate Infiltration Basin (RIB) An artificial impoundment that provides for fluid losses through percolation/seepage as well as through evaporative losses.

Rationing Mandatory water-use restrictions sometimes used under drought or other emergency conditions.

Reasonable-Beneficial Use Use of water in such quantity as is necessary for economic and efficient utilization for a purpose and in a manner which is both reasonable and consistent with the public interest.

Reclaimed Water Water that has received at least secondary treatment and basic disinfection and is reused after flowing out of a domestic wastewater treatment facility.

RECOVER A comprehensive monitoring and adaptive assessment program formed to perform the following for the Comprehensive Everglades Restoration Program: restoration, coordination, and verification.

Reduced Allocation Areas Areas in which a physical limitation has been placed on water use.

Reduced Threshold Areas (RTAs) Areas established by the District for which the threshold separating a General Permit from an Individual Permit has been lowered from the maximum limit of 100,000 GPD to 20,000 GPD. These areas are typically resource-depleted areas where there have been an established history of sub-standard water quality, saline water movement into ground or surface water bodies, or the lack of water availability to meet projected needs of a region.

Regional Water Supply Plan Detailed water supply plan developed by the District under Section 373.0361, F.S.

Retrofit The replacement of existing equipment with equipment that uses less water.

Retrofitting The replacement of existing water fixtures, appliances and devices with more efficient fixtures, appliances and devices for the purpose of water conservation.

Restudy Shortened name for C&SF Restudy.

Reverse Osmosis (RO) Process used to produce fresh water from a brackish supply source.

Saline Water Water with a chloride concentration greater than 250 mg/L, but less than 19,000 mg/L.

Saline Water Interface The hypothetical surface of chloride concentration between fresh water and saline water, where the chloride concentration is 250 mg/L at each point on the surface.

Saline Water Intrusion This occurs when more dense saline water moves laterally inland from the coast, or moves vertically upward, to replace fresher water in an aquifer.

Sea Water Water which has a chloride concentration equal to or greater than 19,000 mg/L.

Seepage Irrigation Systems Irrigation systems which convey water through open ditches. Water is either applied to the soil surface (possibly in furrows) and held for a period of time to allow infiltration, or is applied to the soil subsurface by raising the water table to wet the root zone.

Semi-Closed Irrigation Systems Irrigation systems which convey water through closed pipes, and distribute it to the crop through open furrows between crop rows.

Semi-Confining Layers Layers with little or no horizontal flow, and restrict the vertical flow of water from one aquifer to another. The rate of vertical flow is dependent on the head differential between the aquifers, as well as the vertical permeability of the sediments in the semi-confining layer.

Sensitivity Analysis An analysis of alternative results based on variations in assumptions (a "what if" analysis).

Serious Harm (*Term will be defined during proposed Rule Development process)* An extremely adverse impact to water resources or the environment that is either permanent or very long-term in duration. Serious harm is generally considered to be more intense than significant harm.

Significant Harm *(Term will be defined during proposed Rule Development process)* An adverse impact to water resources or the environment, when the period of recovery from the adverse impact is expected to take several years; more intense than harm, but less intense than serious harm.

Slough A channel in which water moves sluggishly, or a place of deep muck, mud or mire. Sloughs are wetland habitats that serve as channels for water draining off surrounding uplands and/or wetlands.

Stage The elevation of the surface of a surface water body.

Storm Water Surface water resulting from rainfall that does not percolate into the ground or evaporate.

Subsidence An example of subsidence is the lowering of the soil level caused by the shrinkage of organic layers. This shrinkage is due to biochemical oxidation.

Surface Water Water that flows, falls, or collects above the surface of the earth.

Superfund Site A contamination site, of such magnitude, that it has been designated by the federal government as eligible for federal funding to ensure cleanup.

SWIM Plan Surface Water Improvement and Management Plan, prepared according to Chapter 373, F. S.

TAZ Traffic analysis zone; refers to a geographic area used in transportation planning.

Transmissivity A term used to indicate the rate at which water can be transmitted through a unit width of aquifer under a unit hydraulic gradient. It is a function of the permeability and thickness of the aquifer, and is used to judge its production potential.

Turbidity The measure of suspended material in a liquid.

Ultra-low-volume Plumbing Fixtures Water-conserving plumbing fixtures that meet the standards at a test pressure of 80 psi listed below.

Toilets - 1.6 gal/flush

Showerheads - 2.5 gal/min.

Faucets - 2.0 gal/min.

Uplands Elevated areas that are characterized by non-saturated soil conditions and support flatwood vegetation.

Voltinism The number of generations per year.

Wastewater The combination of liquid and waterborne discharges from residences, commercial buildings, industrial plants and institutions together with any ground water, surface runoff or leachate that may be present.

Water Resource Caution Areas Areas that have existing water resource problems or where water resource problems are projected to develop during the next 20 years (previously referred to as critical water supply problem areas).

Water Resource Development The formulation and implementation of regional water resource management strategies, including: the collection and evaluation of surface water and ground water data; structural and nonstructural programs to protect and manage the water resource; the development of regional water resource implementation programs; the construction, operation, and maintenance of major public works facilities to provide for flood control, surface and underground water storage, and ground water recharge augmentation; and, related technical assistance to local governments and to government-owned and privately owned water utilities.

Water Shortage Declaration *Rule 40E-21.231, Fla. Admin. Code:* "If …there is a possibility that insufficient water will be available within a source class to meet the estimated present and anticipated user demands from that source, or to protect the water resource from serious harm, the Governing Board may declare a water shortage for the affected source class." Estimates of the percent reduction in demand required to match available supply is required and identifies which phase of drought restriction is implemented. A gradual progression in severity of restriction is implemented through increasing phases. Once declared, the District is required to notify permitted users by mail of the restrictions and to publish restrictions in area newspapers.

Water Supply Plan District plans that provide an evaluation of available water supply and projected demands, at the regional scale. The planning process projects future demand for 20 years and develops strategies to meet identified needs.

Water Supply Development The planning, design, construction, operation, and maintenance of public or private facilities for water collection, production, treatment, transmission, or distribution for sale, resale, or end use.

Wetlands Areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil conditions.

Wetland Drawdown Study Research effort by the South Florida Water Mangement District to provide a scientific basis for developing wetland protection criteria for water use permitting.

Xeriscape™ Landscaping that involves seven principles: proper planning and design; soil analysis and improvement; practical turf areas; appropriate plant selection; efficient irrigation; mulching; and appropriate maintenance.

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